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MARYLAND SAND CHROME ORE.[1]

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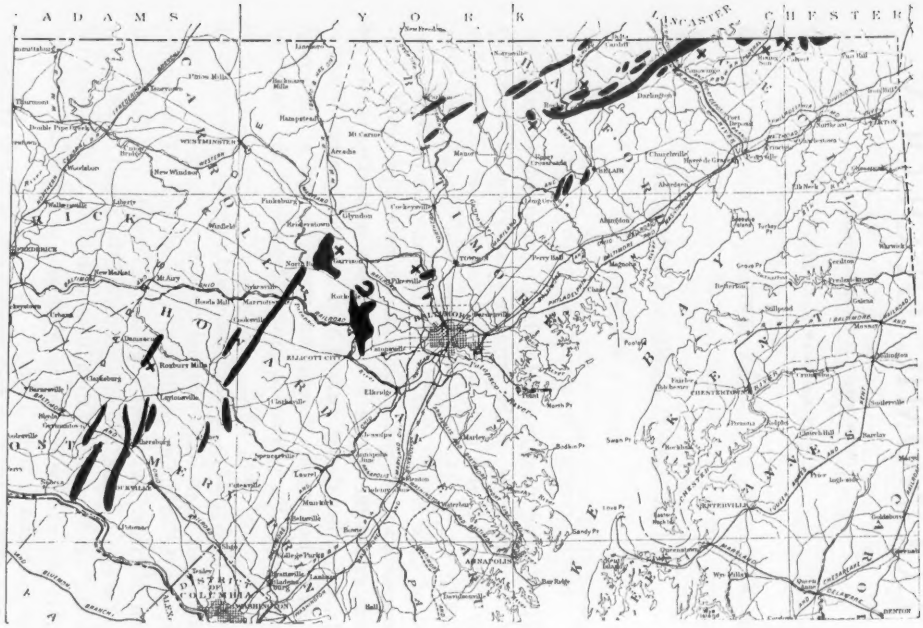
BRIEF ACCOUNT OF MARYLAND CHROME INDUSTRY.

The chrome industry in Maryland commenced with the discovery of chromite on the farm of Isaac Tyson at Bare Hills near Baltimore, at a date usually placed at either 1808 to 1810 or about 1827. The Soldiers Delight region, about ten miles west of Bare Hills, seems to have been discovered soon after. The association of chromite with serpentine was promptly recognized; and as the belt of serpentine rocks extending across the state was rather clearly marked by a belt of "barrens," the discovery of the chromite deposits was made easy and within a very few years all the productive chrome deposits of the state had been discovered (Fig. 15).

From 1828 to 1850, most of the world's supply of chrome ore was shipped from Baltimore and came from deposits in Maryland and the adjoining portions of Pennsylvania. Then competition of larger and richer deposits in Turkish Asia Minor cut into the export trade, and exports practically ceased by 1860. In the late seventies, California ores competed in the domestic market and chrome mining in Maryland as a regular industry came to an end at about 1880.

From 1880 to 1917, no rock chrome was mined in Maryland,

[1] Paper presented before the Geological Society of America, Baltimore, December, 1918, and published with the permission of the State Geologist.


ADAMS
YORK
LANCASTER
CHESTER
FREDERICK
CARROLL
HOWARD
MONTGOMERY
BALTIMORE
HARFORD
CECIL
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QUEEN ANNE'S
TALBOT
CAROLINE
DORCHESTER
WICOMICO
SOMERSET
WORCESTER
ANNE ARUNDEL
PRINCE GEORGE'S
CHARLES
ST. MARY'S
CALVERT
DISTRICT OF COLUMBIA
WASHINGTON
BALTIMORE
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FREDERICK CITY
WESTMINSTER
NEW WINDSOR
MT. AIRY
HOOKS MILL
ROCKVILLE
BROOKEVILLE
DARLINGTON
PERRYVILLE
ABERDEEN
HAVRE DE GRACE
BEL AIR
CHURCHVILLE
FALLSTON
TOWSON
PIKESVILLE
ELKRIDGE
LAUREL
BLADENSBURG
HYATTSTOWN
DAMASCUS
MT. CARMEL
HANOVER
HANOVER JUNCTION
NEW FREEDOM
NEW MARKET
MANCHESTER
HAMPSTEAD
PINEY MEADOWS
LIBERTY
MANSFIELD
PINKSBURG
LIBERTYTOWN
CORBETTSVILLE
ARCADIA
MANCHESTER
MANCHESTER
MANCHESTER

but a small and irregular production of sand chrome persisted throughout that period.

OCCURRENCE OF CHROME SANDS.

Chromite-bearing sands are found not only within the serpentine areas but also for a short distance beyond in streams having their source within the area of those rocks. Productive localities have been along the Maryland-Pennsylvania line in Cecil County, Cherry Hill in Harford County, and Bare Hills and Soldiers Delight in Baltimore County. Cherry Hill in Harford County is the only exception to the rule that important sand chrome areas have also been important producers of rock chrome.

WASHING SAND CHROME.

The method of recovering chromite from the sands of the streams in the serpentine areas has remained the same to the present day, and though the equipment used is simple and inexpensive it is well adapted for the purpose and more feasible economically than would be a more expensive modern equipment. The sands are dug out of the stream bed or the banks of the stream and sifted through a screen of about 8-mesh, whereby the chrome-free coarser gravels are removed. The fines are collected in tubs made by sawing a barrel in half and provided with two long handles so that they can be carried by two men to the buddle at which the sand is concentrated.

The buddle (Fig. 16) is a long narrow trough through which a stream of water is run so that sand fed in the upper end is spread out along the trough and the lighter grains carried out at the lower end. This process is repeated a number of times, each washing increasing the degree of concentration, until the sand is sufficiently concentrated. On each side of the trough is a wooden floor, and the crude sand is piled on one of these and the concentrates shoveled out of the trough are deposited on the other. The trough or trunk of the buddle has a length of 12 feet, width of 12 inches, and depth of about 12 inches. The fall is about 1 to 1½ inches from the upper to the lower end. Buddles are located

Fig. 15. Map of northeastern Maryland, showing areas of serpentine rock (X have been worked.)

close to the bank of the stream from which the sand is obtained, and as the flow of the streams is usually not sufficient to supply the requisite quantity of water, a dam is built back of the buddle in which enough water can be collected to make a run. The water from the dam does not flow directly over the sands, but it is first run through the eye of the buddle, which is a small sec-

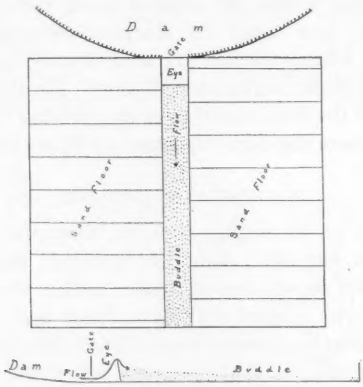


FIG. 16. Plan and longitudinal section of a buddle used in washing chrome sands.

tion at the head of the trough cut off by an inclined partition over which the water flows. The slope desired for this partition by chrome washers varies and some think the best results are obtained if it is vertical. The concentrates are packed in barrels weighing over half a ton for shipment.

ECONOMIC ASPECTS OF SAND CHROME WASHING IN MARYLAND.

In the investigation of the sand chrome industry made a year ago, an interesting situation was encountered. It was found that the cost of production was considerably in excess of the price quoted for chrome ore, and that the selling price of the sand chrome concentrates averaged about twice the quoted price for chrome ores. The reason for this was found to be that the

concentrate is exported to Europe where it is used to set the colors of paintings on fine porcelain ware, for which purpose the Maryland sand chrome appears to be peculiarly adapted. The demand is irregular, but averages about 25 tons annually, a production that can be maintained indefinitely by the chrome-bearing streams. A forced production of only as much as 100 or 200 tons of sand chrome annually, however, would probably exhaust the best localities faster than they are replenished.

It does not appear probable, therefore, that Maryland chrome sands can play a rôle other than that of supplying the small tonnage for the particular purpose for which they appear to be peculiarly adapted.

DESCRIPTION OF SAND CHROME CONCENTRATES.

From an economic standpoint, consequently, the sand chrome deposits merit little attention. Their investigation, however, yielded some results that appear worth while calling attention to.

Five samples of sand chrome concentrates were subjected to screen analysis and chemical analysis. Two of the samples were separated into magnetic and non-magnetic portions with a hand magnet, and those portions were analyzed in order to determine to what extent chromic oxide is present in magnetic ore grains. Four of the samples represent concentrates from the four buddles still in existence and which have been in operation within four years. The fifth sample represents natural concentrate collected from one of the streams in Cecil County.

Screen Analysis.—The screen analyses of the concentrates (Fig. 17) show a similarity in the sizes of the grains of samples II., III. and V., that sample I. is considerably coarser, and sample IV. considerably finer than they. The results are in harmony with the occurrences of the sands from which the concentrates were washed. The sands from which samples II., III. and V. were obtained, were taken from a point in the course of the respective streams within the area of serpentine outcrop and where the grade of the stream was low enough to permit the accumulation of thick coverings of detrital material on the valley

floor. That the sizes of the grains are so nearly alike, is as it should be. The sand from which sample I. was produced came from a relatively higher point in the stream, that is, where much of the stream bed is exposed and the sands accumulate in the riffles and thin coverings of detrital material. Such sand should

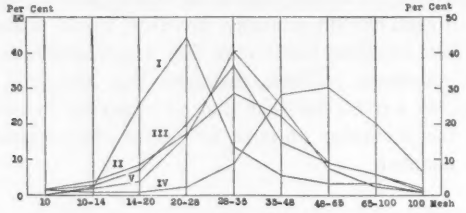


FIG. 17. Screen analysis of five samples of sand chrome concentrates.

Sample I. Concentrate from R. A. Triplet buddle, Soldiers Delight, Baltimore County.

Sample II. Concentrate from the Jay Gore buddle, Soldiers Delight, Baltimore County.

Sample III. Concentrate from the F. A. Dolfield buddle, Soldiers Delight, Baltimore County.

Sample IV. Concentrate from the Adair and Pyle buddle, Rising Sun, Cecil County.

Sample V. Natural concentrate from run west of Rock Springs, Cecil County.

be coarser. Sample IV. was washed from sands at a lower point of the stream course, and beyond the serpentine area. The valley floor at that locality is quite broad and thickly covered with detrital material, and consequently finer sands are encountered.

Chemical Analysis.—The analyses of the concentrates (Fig. 18) show that samples II., III. and V. are much alike in chemical composition also, with the exception of a higher chromic oxide content and lower percentage of iron in sample III. They suggest that the ore minerals consist of chromite in which the trivalent oxide is not alone Cr_2O_3, but to a considerable extent also Al_2O_3 and Fe_2O_3, and in which the bivalent oxide is represented to a small extent by MgO and even CaO, and that mingled with the chromite is a small amount of magnetite. Sample I. is dif-

ferent only in the lower chromic oxide content and higher percentage of iron, which would be explained by the presence of more magnetite, which is not surprising as the serpentine in that vicinity contains small pockets of magnetite.

The composition of sample IV. is quite different. The high silica content is due to the presence of quartz and means only a

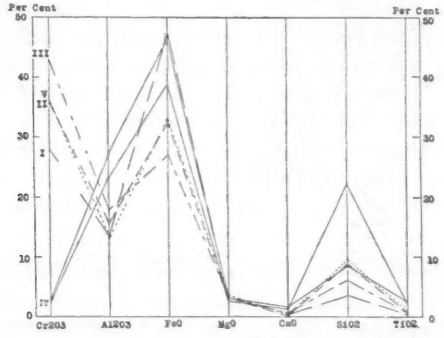


FIG. 18. Analyses of five samples of sand chrome concentrates.

Sample I. Concentrate from the R. A. Triplet buddle, Soldiers Delight, Baltimore County.

Sample II. Concentrate from the Jay Gore buddle, Soldiers Delight, Baltimore County.

Sample III. Concentrate from the F. A. Dolfield buddle, Soldiers Delight, Baltimore County.

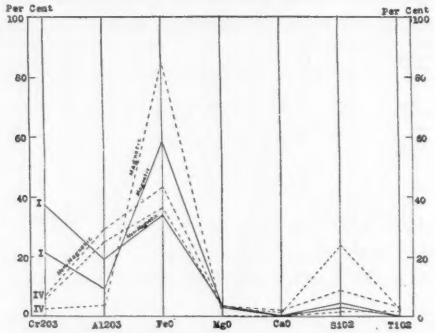
Sample IV. Concentrate from the Adair and Pyle buddle, Rising Sun, Cecil County.

Sample V. Natural concentrate from run west of Rock Springs, Cecil County.

poor concentration. The composition of this sample was recalculated, therefore, on the basis of a silica content equal to that of the other concentrates. The ore minerals have the same appearance in sample IV. as in the other samples. They are made up either of a spinel molecule in which Cr_2O_3 has given way almost completely to Al_2O_3 and Fe_2O_3 or a mixture of a spinel in which Cr_2O_3 has given way to much Al_2O_3 with much magnetite.

In order to get a clearer idea of the nature of the ore particles in the concentrates, a magnetic separation was made of samples I. and IV.

Results of Magnetic Separation (Fig. 19).—The magnetic por-



		Per Cent.	Percentage of Molecules of			
			$MgOAl_2O_3$.	$FeOAl_2O_3$.	$FeOCr_2O_3$.	Fe_3O_4.
Sample I....	Magnetic.....	56.5	16	4	31	49
" "	Non-magnetic..	43.5	19	20	52	9
" "	Mean		18	12	41	29
Sample IV...	Magnetic.....	5.9	0	8	3	89
" " ...	Non-magnetic..	94.1	19	45	10	26
" " ...	Mean		10	26	7	57
Magnetic			18	12	41	29
Non-magnetic			19	45	10	26

FIG. 19. Analyses of magnetic and non-magnetic portions of samples I and IV.

tion of sample I. differs from the non-magnetic portion chemically in having a lower chrome and alumina content and higher iron content. Calculating the composition of each on the basis of the spinel molecules, the magnetic portion has an equivalent of 49 per cent. magnetite, the non-magnetic portion only 9 per cent. magnetite. The magnetic has 20 per cent. molecules with alumina, the non-magnetic 39 per cent. The magnetic portion has 84 per cent. of the molecules containing iron as the bivalent

oxide, the non-magnetic portion has 81 per cent. The mean between the composition of the magnetic and the non-magnetic portions represents a spinel molecule in which the trivalent oxide consists of 30 per cent. alumina, 41 per cent. chromic oxide, and 29 per cent. ferric oxide, and in which 82 per cent. of the bivalent oxide is iron. A particle of this composition may consequently be highly magnetic.

The magnetic portion of sample IV., constituting less than 6 per cent. of the whole, consists of nearly 90 per cent. pure magnetite and contains only iron as the bivalent oxide. The non-magnetic portion of this sample has 64 per cent. molecules with alumina as the trivalent oxide, 10 per cent. chromic oxide, and 26 per cent. ferric oxide, and 81 per cent. molecules have iron as the bivalent oxide.

CONCLUSIONS.

A spinel molecule, therefore, carrying an equivalent of only 29 per cent. magnetite may be highly magnetic if chromic oxide is in excess of alumina; whereas, one carrying an equivalent of 26 per cent. magnetite may be not at all magnetic if the alumina is in excess of chromic oxide. Since alumina reduces the magnetism of the spinel molecule, these figures indicate that a chromite containing no alumina might be highly magnetic if it contains an equivalent of less than 25 per cent. magnetite. Such a chromite would appear to be magnetite in the field and might be disregarded in a search for chrome ore, yet it would analyze 51 per cent Cr_2O_3. On the other hand, a non-magnetic black spinel in a chromite-bearing region, which in the field would appear to be good chrome ore, might run so high in alumina and iron that the chromic oxide content of the ore would fall to less than 7 per cent.

These data point out the inadequacy of simple field tests in prospecting for chrome ore and the necessity of checking such observations by chemical analyses.

PYRITE DEPOSITS IN OHIO COAL.[1]

W. M. TUCKER.

Iron pyrite, the disulphide of iron, FeS_2, is a well-known and widespread mineral. Theoretically it contains 53.46% sulphur and 46.54% iron. Although marcasite is similar in composition, it differs in crystal form and specific gravity; pyrite is cubic and marcasite is orthorhombic; pyrite has a specific gravity of 4.9 to 5.2 and marcasite slightly less. The color of pyrite varies through gold, pale yellow, silver, gray, and tin white. The golden-colored product has given it the names of "fool's gold" and "coal brasses." Its hardness of about 6 makes it troublesome in coal mines and quarries because it dulls edged tools. Because of its tendency to flash fire when struck with steel, it sometimes causes premature explosions during the tamping of blasts. To prevent this all tamping tools are made of copper. Since it is frequently difficult to distinguish between pyrite and marcasite, they are treated as a unit in this paper under the name pyrite.

OCCURRENCE.

Pyrite seldom occurs in a pure state. Some of the common impurities present with it are antimony, arsenic, calcium, carbon, copper, iron oxide, magnesium, lead and zinc; and the presence of any of these impurities decreases the commercial value of the pyrite, although some are much more detrimental than others.[2] The degree of purity of pyrite is measured by its available sulphur and to be of commercial value it must contain 40% or more. Samples taken from the Ohio coal beds show a variation in available sulphur from 23% to 51.2%, but as the samples

[1] Published by permission of the Geological Survey of Ohio.

[2] For further discussion of the effect of impurities in pyrite, see "Sulphur, Pyrite and Sulphuric Acid in 1916," by Philip S. Smith, "Mineral Resources of the United States, 1916," Part II, p. 420.

selected were all of fair quality, much of the pyrite is more impure than these figures indicate.

In occurrence pyrite forms balls, lenses, continuous layers, nodules, thin sheets, flakes, incrustations and fossils. In the coal mines of Ohio the balls usually occur at the top or the base of the coal. They may lie wholly within the coal, wholly within the adjoining strata or between the coal and these strata, but it is very seldom that the bedding plane between the coal and adjoining strata does not either intersect or lie tangent to them. The size of the balls varies from 2 feet in diameter down to the size of nodules, which are simply small balls. The quality of the pyrite in balls is usually poor. Lenses normally occur within the coal along the bedding planes. Most of them are thick in the center and become thinner toward the edges, in which case the edges are sharp. Some of them, however, are thinner in the center than near the edges, in which case the edges are rounded. The largest lenses are about 3 feet in diameter and 6 or 8 inches in thickness at the center, but the normal size is about 1 foot by 2 inches. In any particular mine, these lenses usually occur at a given horizon, along some certain bedding plane. In most cases a thin layer of slate occupies the bedding plane between the edges of the lenses which may be few and far apart or numerous and close together. A continuous layer is simply a case where the deposit has occurred entirely along the bedding plane and may be thought of as the uniting of the edges of numerous lenses, for the layer always varies greatly in thickness. Such layers seldom average more than 2 inches in thickness. Lenses and continuous layers furnish practically all the merchantable pyrite of Ohio. Thin sheets and flakes of pyrite are found in the joint planes of the coal, but these are too small to be recovered. Incrustations sometimes occur on the walls of open faults in the coal. Pyrite replacements forming fossils of plant forms are not uncommon, but are only incidental as a commercial product.

ORIGIN.

The origin of the pyrite is a matter of considerable speculation. Authorities agree that it must have been deposited by cir-

culating water. Ground water dissolves both iron and sulphur as is usually shown by any ground water analysis. It is held that the deposition of pyrite is a reduction process due to the decomposition of organic matter within the coal. It may be that deposition is still in progress within the coal, but this is not known. When the pyrite is exposed to the air oxidation immediately begins changing it to iron sulphate which manifests itself as a white powder upon the walls of the mines and upon pieces of pyrite which are thrown outside the mine. Thus it appears that pyrite must be deposited without the presence of free oxygen.

A peculiar deposit of pyrite occurs in mine No. 38 of the New York Coal Co., at Buchtel, Ohio. A fault has occurred in the coal and an opening about 3 feet high, 6 or 8 inches wide, and several hundred feet long has been formed along the fault plane. On the side walls of this opening were deposits of mammillary pyrite covering several square feet. The faces of coal seemed perfectly fresh, which indicated that the opening had not been filled with ground water. If the opening were not filled with water it seems improbable that it could have been without free oxygen for it is but 200 feet below the surface. However, it is possible, if not probable, that this vent was filled with a mine gas not containing free oxygen.

USES AND PRODUCTION.

Pyrite is used for the manufacture of sulphuric acid. It is roasted in the presence of oxygen which drives off sulphur dioxide as a gas, and this gas is then further oxidized and united with water which forms the acid. The two principal uses of the acid at this time are the manufacture of high explosives and of fertilizers. During normal years the amount of sulphuric acid used in the United States is 3,350,000 tons. This amount suddenly increased when the war began and the amount estimated for 1918 was 10,000,000 tons. One ton of pyrite is sufficient to make two tons of sulphuric acid. Of the 1,675,000 tons of pyrite necessary to manufacture the normal amount of sulphuric acid, about 1,000,000 tons were imported, principally from Spain

and Portugal. When the United States entered the war and the need for all shipping facilities became urgent, the government decided to abandon the importation of pyrite and immediately began a systematic investigation to discover domestic deposits. This investigation was carried on by the Bureau of Mines, and was in charge of Mr. E. A. Holbrook, of the U. S. Mining Experiment Station, Urbana, Ill. The result of this investigation in 1918 shows that there are vast deposits of pyrite and native sulphur in various parts of the country and it is probable that further importation will be unnecessary. The domestic production for 1916 was 423,566 tons, of which Ohio produced 13,551 tons. This output was from twenty-six coal mines in Tuscarawas, Jefferson and Harrison counties.

SCOPE OF WORK.

The writer spent July and August, 1918, in the investigation of the pyrite deposits in the coal mines of Ohio. The method of procedure was to visit mines in each of the coal fields, take measurements of several coal faces in each mine, make estimates and calculations of the workable pyrite in each mine, collect samples and consult superintendents. The samples were sent to the Mining Experiment Station at Urbana, Ill., for analysis. The number of mines visited in each field depended upon conditions in those which were visited and the reports of superintendents and coal operators. If the investigation of a few well-distributed mines and the reports of the superintendents indicated that the deposits in that field could be worked with a profit, a thorough investigation was made. In all, 153 railroad mines were investigated and reported, and besides these several country mines were visited which were not reported. A discussion of the coal beds of Ohio and of the mines investigated follows.

THE COAL MEASURES OF OHIO.

The coal measures of Ohio occupy about one fourth of the area of the State, south and east of a curved line through the centers of Scioto, Licking and Mahoning counties. The bed

rock of this area overlies the older formations to the west and dips 20 or 30 feet per mile toward the east and southeast. Thus in traveling from Newark, Ohio, east to Wheeling, West Virginia, one passes continually from older to younger formations, and crosses the entire rock section of the coal measures of Ohio. The thickness of the formations and members varies greatly in

GENERAL SECTION OF THE COAL MEASURES OF OHIO, NAMING ONLY THE PRINCIPAL COAL MEMBERS.

Formation.	Member.	Remarks.
Dunkard		No coal of value.
Monongahela 200–300 feet.	Waynesburg.	
	Interval.	
	Uniontown.	
	Interval.	
	Meigs Creek, No. 9.	
	Interval.	
	Pomeroy, No. 8A.	
	Interval.	
	Pittsburgh, No. 8.	
Conemaugh 350–500 feet.		Little coal of value.
Allegheny 175–250 feet.	Upper Freeport, No. 7.	
	Interval.	
	Lower Freeport, No. 6A.	
	Interval.	
	Middle Kittanning, No. 6.	
	Interval.	
	Lower Kittanning, No. 5.	
	Interval.	
	Clarion, No. 4A.	
	Interval.	
	Brookville, No. 4.	
Pottsville 250 feet, more or less.	Interval.	
	Tionesta, No. 3B.	
	Interval.	
	Upper Mercer, No. 3A.	
	Interval.	
	Lower Mercer, No. 3.	
	Interval.	
	Quakertown, Wellston, No. 2.	
	Interval.	
	Sharon, Jackson Shaft, No. 1.	
	Interval.	

DATA CONCERNING MINES VISITED.

Map No.	Coal No.	Name of Company.	Name or Number of Mine.	Location.		Coal Production Daily, Tons.	Per Cent. of Pyrite by Weight.	Sample.	Description and Occurrence.	Per Cent. of Sulphur.
				Town.	County.					
1	8A	Pittsburgh Coal	No. 20	Pomeroy	Meigs	650	Very little	None	Occasional lense.	
2	8A	Peacock Coal	Rolling Mill	Pomeroy	Meigs	700	Less than 1%	None	Occasional lense.	
3	8A	Vulcan Coal	Vulcan No. 1	Pomeroy	Meigs	500	3%	A B	Layer on floor Lense within coal	42.46% 44.80%
4	8A	Stalter Essex Coal	No. 1	Pomeroy	Meigs	750	4%	None	Layer on floor. Lenses within coal.	
5	8A	Maynard Coal	Maynard No. 3	Middleport	Meigs	250	.5%	None	Fragmental layer on floor. Occasional lense in coal.	
6	8A	Hocking Domestic	No. 5	Middleport	Meigs	350	3%	A	Layer on floor	44.94%
1	8	J. F. Schuler	Schuler No. 2	Lathrop	Athens	90	Very little	None	Occasional lense in coal.	
2	8	Black Diamond	Black Diamond	Lathrop	Athens	400	2%	A	Lenses and band six inches from base of coal	45.96%
3	8	A. J. Morgan Coal	Johnson	Dilles Bottom	Belmont	650	3%	A B C	Three samples from large boulders at base of coal. Lenses are also present.	38.96% 27.10% 40.82%
4	8	Rail & Rivers	No. 3	Dilles Bottom	Belmont	1800	3%	None	Same as (3).	
5	8	Central Coal Mining	Clifford	Dilles Bottom	Belmont	1200	2%	None	Lenses within coal. See sample D under (18).	
6	8	Cambria Collieries	Webb	Bellaire	Belmont	3000	2%	None	Lenses almost continuous band 16 in. from base of coal. See sample D under (18).	
7	8	Cambria Collieries	Pultney	Bellaire	Belmont	2000	2%	None	Same as (6).	
8	8	Irvin Coal	No. 2	Bellaire	Belmont	200	2%	None	Same as (6).	
9	8	Rail & Rivers	No. 1	Bellaire	Belmont	2500	2%	None	Same as (6).	
10	8	Schichs Coöperative	Schichs	Bellaire	Belmont	250	2%	None	Same as (6).	
11	8	T. W. Parsall	Bakewell	Bellaire	Belmont	900	2%	None	Lenses and nodules in coal. See (18).	
12	8	Rail Rivers	No. 6	Bellaire	Belmont	1800	2%	None	Same as (11).	
13, 14	8	Pittsburgh Belmont	No. 1, 2	Neffs	Belmont	1500, 200	2%	None	Same as (11).	
15	8	J. A. Paisley	Lucy	Stewartsville	Belmont	200	2%	None	Same as (11).	
16	8	A. J. Morgan Coal	Franklin	Stewartsville	Belmont	1000	2%	None	Same as (11).	
17	8	Ohio Consolidated	Ohio	Stewartsville	Belmont	200	2%	None	Same as (11).	
18	8	Purceglove Maher	Purceglove	Stewartsville	Belmont	600	2%	A B C D	Boulder in floor Boulder on floor Boulder in floor Lense within coal	38.96% 28.00% 37.92% 44.18%
19	8	Purceglove Maher	Maher	Stewartsville	Belmont	800	2%	None	Same as (18).	
20	8	Youghiogheny & Ohio	De Lora	Glencoe	Belmont	250	2%	None	Same as (18).	
21	8	Youghiogheny & Ohio	Elinor	Warnock	Belmont	200	2%	None	Same as (18).	

DATA CONCERNING MINES VISITED.—*Continued.*

Map No.	Coal No.	Name of Company.	Name or Number of Mine.	Location.		Coal Production Daily, Tons.	Per Cent. of Pyrite by Weight.	Sample.	Description and Occurrence.	Per Cent. of Sulphur.
				Town.	County.					
22	8	Purceglove Maher....	Heinlein.....	Neffs.....	Belmont..	1500	2%	None	Same as (18).	
23, 24	8	Purceglove Maher....	Willow Grove 1, 2	Neffs.....	Belmont.	500, 800	2%	None	Same as (18).	
25	8	National Coal.....	Loomis.....	Barnesville .	Belmont..	150	1%	None	Occasional lense of poor quality.	
26	8	Lorraine Coal & Dock	Wheeling Creek ..	Lansing.....	Belmont..	1000	2%	None	Lenses and nodules in coal. See (31).	
27	8	Lorraine Coal & Dock	Lansing.....	Lansing.....	Belmont..	1700	2%	None	Same as (26).	
28	8	Lorraine Coal & Dock	Blaine No. 5.....	Blaine.....	Belmont..	1800	2%	None	Same as (26).	
29	8	Fairview Coal.....	Fairview.....	Barton.....	Belmont..	500	1.5%	None	Same as (31).	
30	8	Lorraine Coal & Dock	Crescent No. 3...	Crescent....	Belmont..	1000	1.5%	None	Lenses and nodules in coal. See (31).	
31	8	Clarkson Coal Mining	Clarkson No. 1...	St.Clairsville	Belmont..	1200	1%	A ...	Lenses within coal.....	44.76%
								B ...	Lenses in roof.....	39.44%
32	8	Purceglove Maher....	Lydia.....	Maynard...	Belmont..	600	1%	None	Same as (31).	
33, 34	8	Gt. Lakes Coal Mng..	No. 3, 4.....	Maynard...	Belmont..	1000, 1000	1%	None	Same as (31).	
35	8	Wheeling Tws. Coal Mng.....	Wheeling Tws....	Maynard...	Belmont..	300	1%	A.....	Lenses within coal.....	46.82%
36	8	Leah Mining.....	Leah.....	Maynard...	Belmont..	75	1%	None	Same as (35).	
37	8	Youghiogheny & Ohio	Florence.....	Martins Ferry....	Belmont..	1100	1.5%	None	Lenses flakes and nodules.	
38, 39	8	Pittsburgh & Cleveland.....	Gaylord No. 1, 2..	Martins Ferry....	Belmont..	1000, 1000	1.5%	None	Same as (37).	
40	8	Wheeling Lake Erie ..	No. 2.....	Dillonvale ..	Jefferson..	500	1%	A.....	Lenses within coal.....	45.92%
41	8	Morris Poston.....	Dunglen.....	Dunglen....	Jefferson..	1000	1%	None	Same as (40).	
42	8	Gt. Lakes Coal Mng..	Ramsey.....	Adena.....	Jefferson..	1500	1%	None	Same as (40).	
43	8	Gt. Lakes Coal Mng..	Robyville.....	Aedna.....	Jefferson..	1100	1%	None	Same as (40).	
44	8	Adena Coal.....	No. 1 (stripper) ..	Adena.....	Jefferson..	300	1%	None	Same as (40).	
45	8	Short Creek Coal....	No. 2.....	Adena.....	Jefferson..	1000	1%	None	Same as (40).	
46	8	Cambridge Colleries..	Majestic.....	Blairmont ..	Jefferson..	900	Very little	None	Occasional lens.	
47	8	Pittsburgh Block....	No. 3.....	Kenwood...	Jefferson..	175	Very little	None	Occasional lens.	
48	8	Massillon Coal Mng..	Rose (stripper)...	Hopedale...	Jefferson..	700	1%	None	Same as (40).	
49	8	Harmon Creek Coal..	Howard (stripper)	Hopedale...	Jefferson..	400	Very little	None	Patchy lenses.	
50, 52	8	Wayne Coal.....	No. 2, 3 (stripper)	Parlette....	Jefferson..	2000, 2000	No pyrite.			
51, 53	8	Wayne Coal.....	No. 1, 4 (stripper)	Parlette....	Jefferson..	1200, 1100	Practically none.			
54	8	Beluau Coal.....	Smithfield (stripper).....	Smithfield ..	Jefferson..	600	No pyrite.			
55	8	United States Coal...	Crow Hollow.....	Bradley.....	Jefferson..	1500	Little.	None	Patchy in mine. More in south part.	
56	8	Glens Run Coal.....	Jug Run.....	Dillonvale ..	Jefferson..	1000	1%	None	Same as (40).	

DATA CONCERNING MINES VISITED.—*Continued.*

Map No.	Coal No.	Name of Company.	Name or Number of Mine.	Location.		Coal Production Daily, Tons.	Per Cent. of Pyrite by Weight.	Sample.	Description and Occurrence.	Per Cent. of Sulphur.
				Town.	County.					
57	8	Glens Run Coal.....	Rush Run No. 4..	Rush Run ..	Jefferson..	800	1%	None	Same as (40).	
1	7	Nixon Edington Coal.	Nixon Edington ..	Nelsonville .	Athens....	150	1.5%	A ...	Lens with greenish color.....	44.40%
								B ...	Lens with brassy color.....	44.50%
								C ...	Band at base of coal.....	23.20%
2	7	New York Coal.....	No. 36.....	Buchtel.....	Athens....	900	2% in ⅔ of mine	A ...	Lens from coal.....	51.20%
								B ...	Similar lens but thinner.....	41.60%
3	7	Chauncey Coal.....	No. 17.....	Chauncey...	Athens....	140	Little	None	Occasional patch on floor.	
4	7	Pan American Coal...	Sedalia.....	Jacksonville	Athens....	600	No pyrite			
5	7	W. P. Rice Mining...	Palos.....	Glouster....	Athens....	200	No pyrite			
6	7	Cambridge Collieries .	Caldwell.....	Cambridge..	Guernsey .	1600	No pyrite			
7	7	Cambridge Collieries .	Coal Ridge.....	Cambridge..	Guernsey .	1200	No pyrite			
8	7	Cambridge Collieries .	Blue Bell.....	Cambridge..	Guernsey .	1400	No pyrite			
9	7	National Coal.....	Little Kate No. 2.	Cambridge..	Guernsey .	900	No pyrite			
10	7	National Coal.....	Minnehaha.....	Cambridge..	Guernsey .	1000	5% in places	A.....	See discussion in text.....	47.90%
11	7	National Coal.....	Murray.....	Cambridge..	Guernsey .	New mine	No pyrite			
12	7	National Coal.....	Harreyette.....	Cambridge..	Guernsey .	1150	5% in places	None	Same as (10).	
13	7	National Coal.....	Little Kate No. 1.	Cambridge..	Guernsey .	1200	No pyrite			
14	7	Cambridge Collieries .	Banner.....	Cambridge..	Guernsey .	1000	No pyrite			
15	7	Cambridge Collieries .	Buffalo.....	Cambridge..	Guernsey .	1500	No pyrite			
16	7	Cambridge Collieries .	Walhonding No. 2	Cambridge..	Guernsey .	1500	No pyrite			
17	7	Cambridge Collieries .	Hartford.....	Cambridge..	Guernsey .	650	No pyrite			
18	7	Cambridge Collieries .	Trail Run No. 2..	Cambridge..	Guernsey .	800	No pyrite			
19	7	Cambridge Collieries .	Trail Run No. 1..	Cambridge..	Guernsey .	1350	No pyrite			
20	7	Cambridge Collieries .	Ideal.....	Cambridge..	Guernsey .	1200	No pyrite			
22, 23	7	Forsythe Coal.....	No. 2, 1.....	Cambridge..	Guernsey .	1000, 1400	Nc pyrite			
(21, 24) 25, 27	7	Akron Coal Co.....	All Mines.....	Cambridge..	Guernsey .	3000	No pyrite			
26	7	Morris Coal.....	Black Top.....	Lore City...	Guernsey .	1150	No pyrite			
28	7	Morris Coal.....	Cleveland.....	Senecaville..	Guernsey .	900	Trace			
29	7	Goshen Central Coal..	Laurel Valley.....	Stillwater...	Tuscarawas....	250	No pyrite			
30	7	Storm Lumas Coal...	Kirk.....	Salineville ..	Carrol....	300	No pyrite			
31	7	Sterling Coal Ltd.....	Sterling.....	Salineville ..	Carrol....	1000	No pyrite			
1	Stray	F. L. Euga Coal.....	Myrtle.....	Newcomerstown.....	Tuscarawas	150	2.75%	None	Lenses, bands and nodules, impure.	
1	6	Ohio Collieries.....	No. 210	Poston.....	Athens....	1400	No pyrite			
2	6	Pittsburgh Coal.....	No. 9	Nelsonville .	Athens....	1550	Trace			
3	6	New York Coal.....	No. 3	Nelsonville .	Athens....	No record	No pyrite			
4	6	New York Coal.....	No. 31	Buchtel.....	Athens....	450	No pyrite			

DATA CONCERNING MINES VISITED.—*Continued.*

Map No.	Coal No.	Name of Company.	Name or Number of Mine.	Location.		Coal Production Daily, Tons.	Per Cent. of Pyrite by Weight.	Sample.	Description and Occurrence.	Per Cent. of Sulphur.
				Town.	County.					
5	6 & 7	Ohio Collieries	301 Congo	Congo	Perry	650	1% of all	A	Nodules and lenses in base and top of No. 6, no pyrite in No. 7. Total coal thickness 13 feet	43.52%
6	6	Olmsted Coal & Mining	White Oak	Moxahala	Perry	150	2%	A	Nodule from top of coal	45.66%
								B	Lense from body of coal	43.40%
7	6	Ohio State Brick & Stone	Moxahala	Moxahala	Perry	80	1.5%	A	Lense about 13 in. from top	44.00%
8	6	Ohio Central Coal	Ohio Central	Moxahala	Perry	200	1%	None	Thin layers, very impure.	
9	6	Loyal Coal	Loyal	Moxahala	Perry	100	1%	None	Impure, not marketable.	
10	6	Roberts Coal Mining	Roberts	New Lexington	Perry	100	Little	None	Impure.	
11	6	The Red Run Mining	No. 66	New Lexington	Perry	150	1%	None	Impure, not worth developing.	
12	6	Big Six Coal	Big Six	Shawnee	Perry	200	Little	None	Impure, not worth developing.	
13	6	Lewis & Davis	Lewis & Davis	Shawnee	Perry	40	Little	None	Fair grade but too small quantity to warrant development.	
14	6	Standard Hocking Coal	Rends	Crooksville	Perry	350	Little	None	All forms, impure.	
15	6	Elk Coal	Elk No. 1	Roseville	Muskingum	450	Little	None	Impure, not worth developing.	
16	6	Ohio Service	No. 6	Conesville	Coshocton	200	Little	None	Poor grade.	
17	6	Stillwater Coal	Tippecanoe	Tippecanoe	Harrison	350	2.5%	A	Lense from middle vein	38.00%
								B	Nodule from base of coal	38.10%
18	6	Evans Clay Manufacturing	No. 1	Urichsville	Tuscarawas	75	2%	None	Middle band interrupted by black slate.	
19	6	Indian Hill Coal	Indian Hill	Urichsville	Tuscarawas	250	5%	None	Middle band continuous.	
20	6	Scott Coal	D No. 1	Midvale	Tuscarawas	150	4.5%	None	Middle band continuous, some nodules in base.	
21	6	Midvale Coal	Midvale No. 4	Midvale	Tuscarawas	500	5%	A	Middle band continuous	40.00%
								B	Nodules in base of coal	44.00%
22	6	Andreas Coal	No name	New Philadelphia	Tuscarawas	150	3%	None	Middle band interrupted by black slate.	
23	6	Akron Coal	Silver Creek	New Philadelphia	Tuscarawas	300	5%	None	Middle band continuous.	
24, 25	6	Midvale Goshen Coal	No. 6, 7	New Philadelphia	Tuscarawas	500, 500	5%	None	Middle band continuous.	

DATA CONCERNING MINES VISITED.—*Continued.*

Map No.	Coal No.	Name of Company.	Name or Number of Mine.	Location.		Coal Production Daily, Tons.	Per Cent. of Pyrite by Weight.	Sample.	Description and Occurrence.	Per Cent. of Sulphur.
				Town.	County.					
26	6	Canton Drop Forge Mining	Forge	New Philadelphia	Tuscarawas	100	4.5%	A B C	Gray lense from middle band Golden lense from middle band Weathered lense from dump	33.50% 48.10% 42.50%
27	6	Reeves Coal	No. 2	New Philadelphia	Tuscarawas	500	5%	A	Nodules in base of coal	48.60%
28	6	James Mullins Coal	No. 2 & 3	New Philadelphia	Tuscarawas	400	5%	A B	Middle band continuous Middle band continuous	44.30% 41.60%
29	6	Goshen Central Coal	Honey Run	New Philadelphia	Tuscarawas	425	4.5%	None	Middle band continuous.	
30	6	Horger & Heldt Coal	H mine	New Philadelphia	Tuscarawas	200	5%	None	Middle band continuous.	
31	6	Cleveland Canton Coal	C mine	New Philadelphia	Tuscarawas	350	3.5%	A	Middle band continuous	43.50%
32	6	Horger & Heldt Coal	D mine	New Philadelphia	Tuscarawas	200	5%	None	Middle band continuous.	
33	6	Akron Coal	E mine	New Philadelphia	Tuscarawas	550	3%	None	Middle band sometimes interrupted by black slate.	
34	6	Schneider Coal	No. 5 Goshen Valley	New Philadelphia	Tuscarawas	100	5%	None	Middle band continuous.	
35	6	Laughlin Coal	Laughlin	Mineral City	Tuscarawas	50	5%	None	Middle band continuous.	
36, 37	6	Youghiogheny & Ohio	No. 1, 2	Amsterdam	Jefferson	800, 500	2%	None	Nodules and boulders in top and base of coal, very impure.	
38	6	Ohio & Pennsylvania	No. 1	Amsterdam	Jefferson	1200	2%	None	Same as (36).	
39	6	Ohio & Pennsylvania	No. 1	Bergholz	Jefferson	1200	2%	None	Same as (36).	
40	6	W. H. Warner Coal	Wolf Run	Amsterdam	Jefferson	1200	2%	None	Same as (36).	
41	6	Geo. Enos, owner	Strabley No. 1	Salineville	Columbiana	200	Little pyrite	None	Lenses not worth developing.	
42	6	Big Vein Coal	Garside	Salineville	Columbiana	550	Little pyrite	None	Occasional small lense or nodule.	
43	6	Jones & Wilson Coal	No name	Salem	Columbiana	150	Trace			
1	5	Ginn Coal	Red Devil	Ironton	Lawrence	20	No pyrite			
2	5	Halley Coal	No. 5	Pedro	Lawrence	250	No pyrite			
3	5	Superior Collier	Superior No. 10	Wellston	Jackson	80	No pyrite			
4	5	The Wayne Mining	Mary Jean	Cambridge	Guernsey	250	1%	A	Lense from coal	42.40%
5	5	Kimbolten Coal Mining	Walters	Kimbolten	Guernsey	New mine	1.5%	None	Lenses, impure.	
6	5	Kimbolten Coal Mining	Rice	Guernsey	Guernsey	New mine	Very little	None	Thin bands interbedded with coal.	
7	5	Kimbolten Coal Mining	Buckhorn	Newcomerstown	Tuscarawas	50	2%	None	Lenses, bands, nodules, impure.	

DATA CONCERNING MINES VISITED.—*Continued.*

Map No.	Coal No.	Name of Company.	Name or Number of Mine.	Location.		Coal Production Daily, Tons.	Per Cent. of Pyrite by Weight.	Sample.	Description and Occurrence.	Per Cent. of Sulphur.
				Town.	County.					
8	5	Geo. J. Markley, owner	Huff Run	Mineral City	Tuscarawas	100	5%	None	Lenses throughout coal. Good quality and easily cleaned.	
9	5	Laughlin Coal	Laughlin	Mineral City	Tuscara-	50	6%	None	Same as (8).	
1	4A	Superior Collier	Superior No. 10	Wellston	Jackson	20	No pyrite			
2	4A	Brown Coal	Iron Valley	Wellston	Jackson	100	Very little	None	Lenses, very impure and not worth developing.	
3	4A	Woodrow Coal & Mining	Woodrow	Wellston	Jackson	250	Very little	None	Lenses, very impure and not worth developing.	
1	3	Sterling Coal Limited	Delmore	Leetonia	Columbiana	200	2%	A B	Best quality balls in coal Same as A but more impure	46.90% 43.70%
2	3	United Iron & Steel	Cherry Valley	Leetonia	Columbiana	75	1%	A	Lense of best pyrite in mine	38.70%
3	3	Salem Mining	Salem	Salem	Columbiana	70	Very little	None	Much like 1 and 2 but more impure.	
1	2	Twin Ada Coal	Twin Ada	Glen Roy	Jackson	75	Trace			
2	2	Armstrong Coal	Armstrong	Jackson	Jackson	100	Trace			
3	2	Maynard Coal	Wainwright	Wellston	Jackson	150	No pyrite			

different localities. This is well shown in the various coal beds which range from workable thickness in one locality to mere traces in another. There are recognized in all about thirty horizons of coal in Ohio and twelve of these have been worked for railroad shipment. The general section on page 202 shows the relations of the principal coal members.

METHODS OF CLEANING PYRITE.

When coal is blasted or picked from the face in the mine the pyrite falls with it. The lenses and nodules usually fall more or less free from the coal but never entirely so, and in some cases much coal or slate will adhere to the pyrite. In order to market the pyrite it is necessary to separate it from the adhering impurities. This is accomplished by either of two methods—hand cleaning or crushing and washing. Hand cleaning only is used in Ohio at present. The cleaner, with a special hammer resembling a bricklayer's, chips off the adhering coal and slate and can prepare from three to six tons of pyrite per day, according to the tenacity of the adhering impurities. Cleaners' wages vary according to the ease with which the pyrite can be cleaned, and they range from $0.75 to $1.50 per ton.

METHODS OF DELIVERING PYRITE FROM MINE TO RAIL.

There are different methods of procedure used by different mines in moving the pyrite from mine to rail. *Method A.*—The miner throws the uncleaned pyrite aside from the mine gob. The cleaner goes from room to room and cleans all each miner has accumulated. When he has prepared a flat carload or more, it is transported from the mine on Sunday or outside regular hours by miners on overtime. *Method B.*—The miner throws the pyrite aside until he has a mine carload, and then it is removed with the regular coal haul. At the mine mouth the car is shunted to the cleaning yard where a workman unloads and cleans the pyrite. When he has a flat carload ready it is reloaded into mine cars, outside regular work hours, and dumped through the coal tipple. In this case the miner is paid by the ton for cleaning and

regular day wages are paid for loading it into the flat. *Method C.*—The workman removes the uncleaned pyrite from the mine as in the preceding method. At the mine mouth the car is sent to a specially built cleaning room and pyrite tipple where the car is dumped into the cleaning room. Here it is cleaned and thrown directly into a bin which can be dumped into the railroad flat. *Method D.*—The miner cleans his own product at times when he is not supplied with mine cars. When the miners have accumulated a flat carload, it is removed on extra time. *Method E.*—This method is used when the coal is cleaned on a picking table. The pyrite is not separated from the coal until it reaches the picking table. From there it is thrown into a cleaning room where it is handled as in method C. This plan is employed in some stripping mines where the coal is loaded by steam shovel. It is the simplest method of handling pyrite. There is much discussion as to which of the methods is the most practical. It seems that C is the most systematic, but D has strong supporters because it tends to keep miners employed if they are not supplied with mine cars, when ordinarily they would stop work for the day.

CURRENT PRICES.

The cost of delivering the clean pyrite to the railroad car varies from $1.50 to $3.00 a ton according to the ease of cleaning, the method of delivery and the general conditions at the mine. The price of the clean pyrite f.o.b. at the mine has been from $3.70 to $6.25 a ton, according to the contract which the chemical companies could get the mine operators to sign. The Grasselli Chemical Co. of Cleveland has contracted for most of the Ohio product in recent years and the contract price for 1918 was $3.70 to $4.05 a ton. The American Steel and Wire Co. paid at the same time for the same grade of pyrite $6.25 a ton.

In regular pyrite mining regions such as are found in Georgia and other states, the standard for selling pyrite is the unit or percentage of available sulphur. Thus a pyrite which tests 40% sulphur would sell on the basis of 40 units. The standard price for pyrite which is not produced from coal is 20 cents to 30 cents

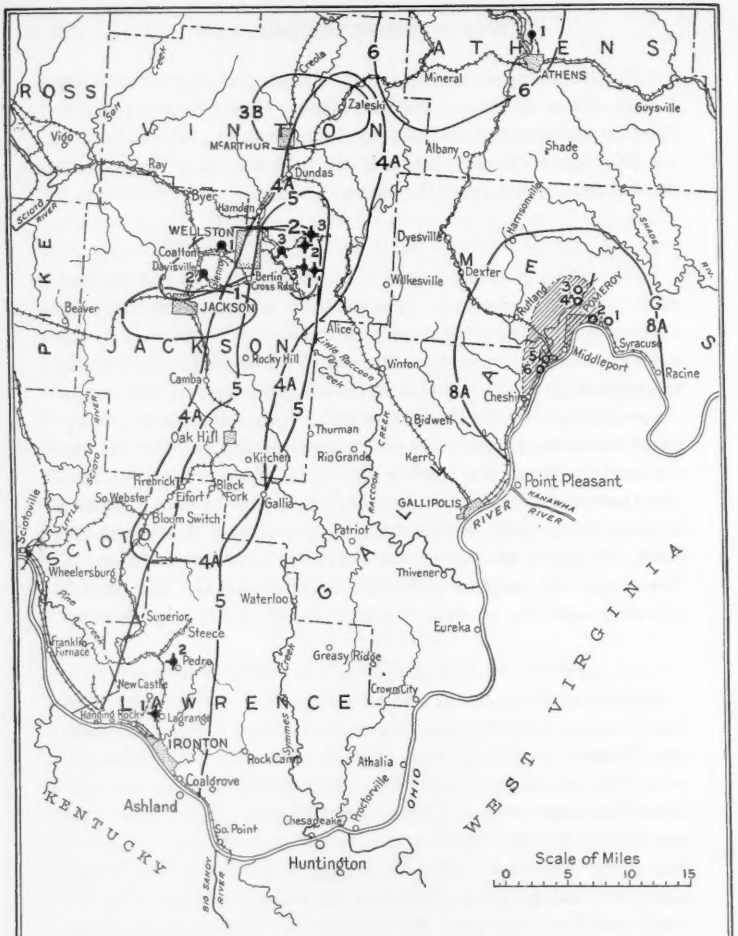
a unit; therefore a 40-unit pyrite at 30 cents would sell for $12.00 and at 20 cents for $8.00 a ton. Coal pyrite is less valuable because the carbon present colors the acid. While this does not interfere with the quality of the acid nor its principal commercial uses, it decreases the market value.

PYRITE DEPOSITS IN THE COAL MEMBERS.

Each of the coal beds of Ohio contains more or less sulphur, as is shown by analyses. However, a coal analysis indicates nothing as to the commercial pyrite which it contains. In collecting a sample for analysis the sampler takes a vertical section throughout a typical coal face in the mine, but rejects any part of the section which the miner discards. Since the miner is supposed to throw out all pyrite of commercial size, the sampler also discards it. Thus, the sulphur shown by an ordinary coal analysis represents the finely disseminated sulphur, either combined or free, which exists within the coal, and certain thin layers and flakes of pyrite which are too small to be discarded from it. Therefore, the sulphur indicated by analysis has no bearing whatever upon the amount of pyrite which a mine may contain.

COALS OF THE POTTSVILLE FORMATION.

The coals of the Pottsville formation have no pyrite of commercial value. The Sharon, No. 1, coal, which is mined in Jackson County, is entirely free from this mineral. The Quakertown, No. 2, coal, also mined in Jackson County, has an occasional lens with traces of flakes and nodules. The Lower Mercer, No. 3, coal is mined in two small areas in Coshocton and Mahoning Counties. The Coshocton County coal is largely cannel and has no pyrite; whereas the Mahoning County area is small and has very few working mines. The Delmore mine, Sterling Coal Co., Ltd., is the largest in the area and it also contains the highest percentage of pyrite. The mineral is of good quality as shown by the analysis, but it is difficult to clean. The coal and slate adhere to it so tenaciously, that it is almost impossible to prepare the pyrite for market. If it were crushed and



LAWRENCE, GALLIA, JACKSON, MEIGS, VINTON, AND PARTS OF ADJACENT COUNTIES.

EXPLANATION

Developed Coal Areas.... 4A

Pyrite Area.....

MINES

Number 2 Coal = No. 4A = No 5 =

No. 6 = No. 8A =

FIG. 20.

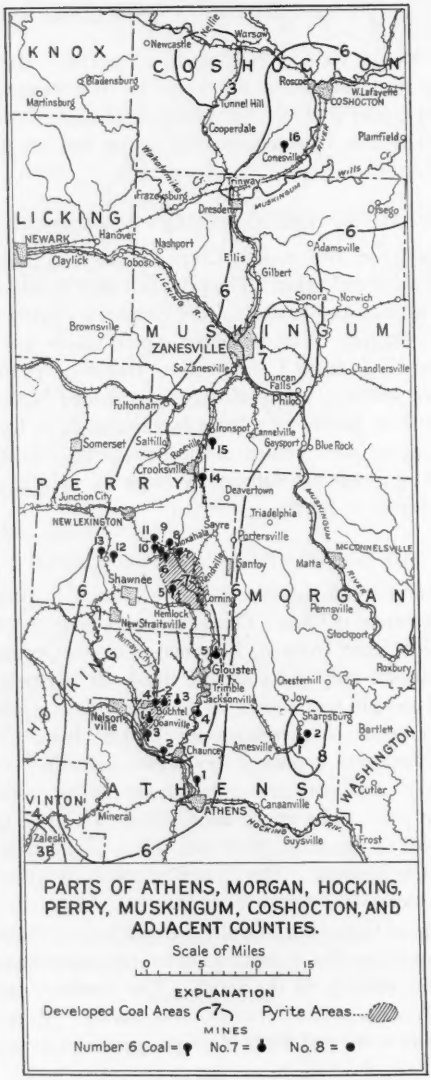
washed it would yield a fair grade of pyrite. However, the quantity is so small that it can never be of commercial importance. The Upper Mercer, No. 3A, and Tionesta, No. 3B, coals are practically free from commercial pyrite and are mined on a very small scale.

COALS OF THE ALLEGHENY FORMATION.

The Brookville, No. 4, and Clarion, No. 4A, coals have no pyrite of commercial value. The principal area in which Clarion, No. 4A, coal is mined extends from northern Vinton to central Lawrence Counties. The principal mines which are southeast of Wellston in Jackson County show traces of pyrite, but of very impure quality. It is closely interbedded with coal and slate and seldom occurs in a lense large enough to have market value. No mines were visited in the Brookville, No. 4, which is not worked in quantities sufficiently large to make it of importance as a source of pyrite.

THE LOWER KITTANNING, NO. 5, COAL.

The Lower Kittanning, No. 5, coal is mined in two areas of considerable extent in Ohio. One of these extends in a belt about 10 miles wide from Ironton, Lawrence Co., to Oreton, Vinton Co. This shows only the slightest traces of pyrite and not a single hand sample was found in the three mines visited. The other area extends in a crescent-shaped belt from Cambridge, Guernsey County, to a point a few miles southeast of Canton, Stark County, and contains considerable pyrite, especially in the northern part. The mines about Mineral City, Tuscarawas County, have as much as 5 or 6% of a high-grade product which is easily cleaned. The Laughlin mine, at Mineral City, prepares an occasional flat load, which is sold to the Grasselli Chemical Co,, of Cleveland, for about $4.00 a ton. On map (Fig. 22), this part of the No. 5 area has been included with the No. 6 which lies immediately to the south. The southern end of this No. 5 area has no pyrite of commercial value. Moreover, the coal tonnage is small and there is no prospect of increase.



PARTS OF ATHENS, MORGAN, HOCKING, PERRY, MUSKINGUM, COSHOCTON, AND ADJACENT COUNTIES.

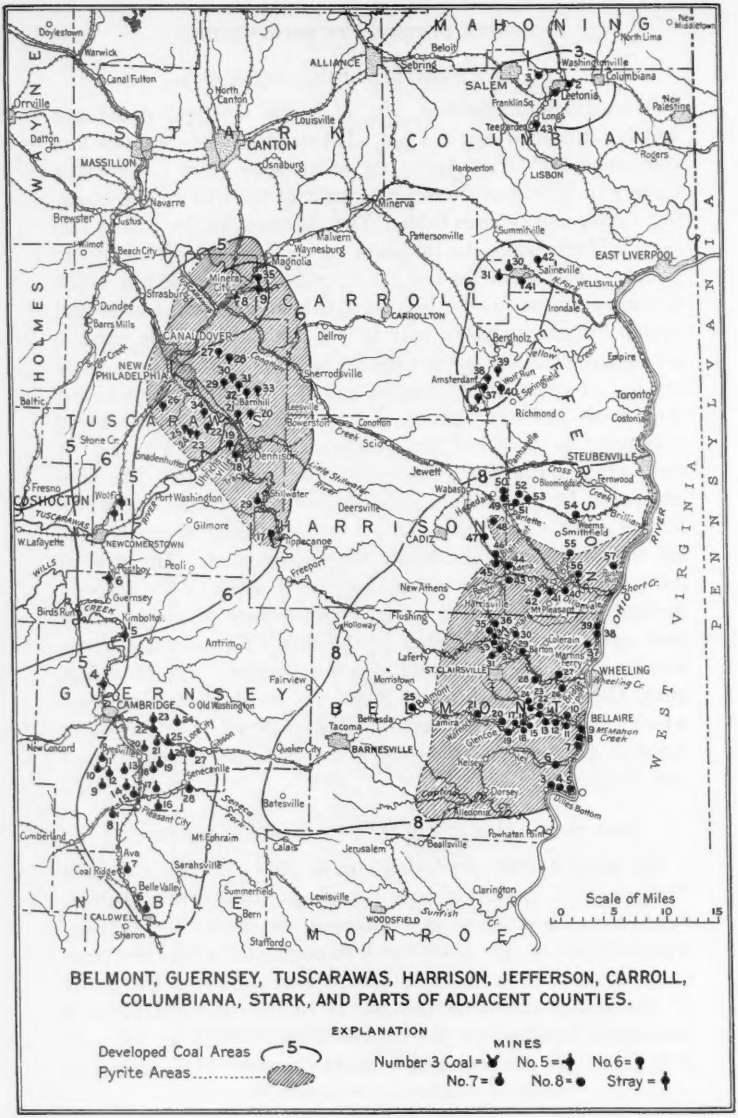
FIG. 21.

THE MIDDLE KITTANNING, NO. 6, COAL.

The Middle Kittanning, No. 6, is the most persistent and widely distributed coal in Ohio. It extends across the State in a continuous belt from 10 to 25 miles wide from Columbiana County to Lawrence County and includes the well-known Hocking Valley and Goshen fields. The character of the coal is also very uniform while the thickness varies ordinarily from 5½ to 3 feet. Everywhere the bed has a parting near the middle which is known as the middle band, and which consists of slate and pyrite. In the southern part of the State the middle band is principally slate, and pyrite deposits south of Tuscarawas County are not of commercial value except in a small area containing three mines in Perry County. These mines, which are numbered 5, 6 and 7 in the list of No. 6 mines, contain from 1 to 2% of clear white pyrite which cleans easily and tests high. The mineral forms lenses about 13 inches from the top of the coal which is here about 4 feet thick, but an occasional lens occurs both at the top of the coal and below the middle band. The row of mines northwest of Moxahala along the T. & O. C. Ry. shows a gradual decrease in both quantity and quality of pyrite as the coal rises higher and higher in the hills. Considerable pyrite was formerly sold from a mine in this vicinity. The Moxahala mine, Ohio State Brick and Stone Co., is the only one from which pyrite is now recovered. This small area could produce 2,000 to 3,000 tons of the mineral a year at the present rate of coal production.

THE TUSCARAWAS COUNTY OR GOSHEN DISTRICT.

The greatest pyrite producing area in Ohio is the No. 6 field in Tuscarawas County which is known as the Goshen District. Reference to Nos. 18 to 35 inclusive in the list of No. 6 mines will show percentages from 2 to 5 throughout the field and most of the analyses indicate more than 40% of sulphur. The pyrite of this field is almost entirely in the middle band and forms a continuous layer where the mineral runs as high as 5%. It falls free from the coal and is easily cleaned. Many mines in



BELMONT, GUERNSEY, TUSCARAWAS, HARRISON, JEFFERSON, CARROLL, COLUMBIANA, STARK, AND PARTS OF ADJACENT COUNTIES.

EXPLANATION

Developed Coal Areas 5

Pyrite Areas

MINES

Number 3 Coal = No. 5 = No. 6 =

No. 7 = No. 8 = Stray =

FIG. 22.

the district now recover pyrite and Nos. 27 and 28 are the largest producers in the State. Each markets more than 2,000 tons a year. The mines which at present recover pyrite are Nos. 18, 20, 21, 23, 28, 29, 31, 33 and 35. Several others have recently discontinued saving it because of the shortage of coal miners and the low price paid for clean pyrite. The total yearly production of coal from the Goshen District is in excess of 2,000,000 tons, and since the average amount of pyrite which is either discarded or recovered is more than 4%, the possible production in this field is not less than 80,000 tons a year.

A small group of No. 6 mines is found near Amsterdam and Bergholz in Jefferson County. These have a great deal of very impure pyrite, but none of it is of commercial value. Some of this pyrite is beautifully fossilized and is usually a replacement of vegetable forms.

No mines were visited in the Lower Freeport, No. 6A, coal. In fact, there are few mines in this bed in the State.

THE UPPER FREEPORT, NO. 7, COAL.

The Upper Freeport, No. 7, coal contains very little commercial pyrite. The three principal areas in which this coal is mined are in northern Athens and southern Perry Counties, northern Noble and southern Guernsey Counties, and southern Columbiana County. In the first-named area there are two mines worthy of notice and these are numbered 1 and 2 in the list of No. 7 mines. The pyrite is conspicuous in these because of the large size of the lenses. Sample A from mine 2 is remarkable for its purity, but the deposit seems to be very local and hence of little importance. Mine, No. 3, which is less than a mile from No. 2, shows very little pyrite and other near-by mines show none. In the Noble-Guernsey County area there are but two mines, Nos. 10 and 12, which contain any pyrite. They normally have a slate roof, but here and there sandstone horsebacks occur which fill valley-like depressions in the coal and may cut it out. Wherever these horsebacks occur, great deposits of pyrite are present in the form of boulders. They are imbedded in the coal on either side of the

horseback and the miners therefore take these boulders as evidence that a horseback is near. The high quality of this pyrite is shown by Sample A from mine no. 10, but since these deposits occur in only local areas in these two mines they are not considered of commercial importance.

COALS OF THE MONOGAHELA FORMATION.

THE PITTSBURGH, NO. 8, COAL.

The greatest coal producing bed in Ohio is the Pittsburgh, No. 8. The area is located mainly in Belmont, Harrison and Jefferson Counties, where the thickness of the coal is 5 feet more or less. It is overlain by about 16 inches of draw slate which must be taken down, and this makes a very heavy gob. By reference to the list of No. 8 mines it is apparent that pyrite deposits ranging from 3% in the south to 1% in the north occur in this coal. The accompanying analyses show it to be of high grade except for the boulder deposits in the extreme south. The heavy gob akes the recovery of this pyrite difficult because it is hard to ep the two separated, but in spite of this handicap several mines in the northern part of the area are recovering it. These include Nos. 40, 44, 47, 48, 56 and 57, some of which are stripping mines where the difficulty due to the draw slate is not encountered. A peculiarity of the pyrite in this bed is its tendency to disappear from the crop coal. In the extreme northern part around Smithfield and Hopedale there is no pyrite, due probably to the oxidation of the pyrite to sulphate of iron which is removed by ground water. The total yearly coal production in this area is about 15,000,000 tons and the average amount of pyrite is more than 1%. This gives a possible yearly production of at least 150,000 tons. Two small mines operate in No. 8 coal at Lathrop in Athens County. One of these contains about 2% of pyrite and the other much less. This deposit is not considered of commercial importance.

THE POMEROY, NO. 8A, COAL.

A considerable area of Pomeroy, No. 8A, coal is mined in Meigs County where the bed is 5 feet more or less in thickness.

It contains deposits of pyrite in the center of the area, but the crop coal has very little. The number of productive mines is small and none are now recovering the mineral. The total estimate for this area is about 15,000 tons a year.

No investigation was made of the Meigs Creek or higher coals because they are not now worked in a large way for railroad shipment.

SUMMARY.

The lower coals of the State contain no commercial pyrite. The great productive areas are with the Middle Kittanning, No. 6, and the Pittsburgh, No. 8, with smaller areas in the Pomeroy, No. 8A, the Upper Freeport, No. 7, and the Lower Kittanning, No. 5, coals. The total possible production of pyrite is in round numbers 250,000 tons yearly. It is distributed as follows: No. 8, 150,000 tons; No. 6, 80,000 tons; No. 8A, 15,000; all others, 5,000 tons.

ACKNOWLEDGMENT.

The writer wishes to express his appreciation and thanks to mine operators, superintendents and others for many accommodations which were accorded during this investigation. Especial thanks is due Prof. J. A. Bownocker, State Geologist of Ohio, Mr. E. A. Holbrook, Director of the Pyrite Investigation, and Mr. Wilber Stout, assistant geologist, for valuable advice and criticism in the field work and in the preparation of this paper and Prof. W. D. Turnbull, who prepared the drawings.

NOTES ON THE GEOLOGY OF THE DIAMOND REGION OF BAHIA, BRAZIL.

By Roderic Crandall.[1]

INTRODUCTORY.

The first description of the geology of the Diamond District of Bahia that gave a definite idea of the structure of the region was written by O. A. Derby and published at Bahia in 1905.[2] During the year of 1907 further work was carried on, in cooperation with the Brazilian Geological Survey, in the Morro do Chapeo and Lençoes district by Dr. John C. Branner, the writer acting as his assistant. Dr. Branner has published some of his results in a series of contributions.[3]

Later the writer was appointed geologist of the Brazilian Geological Survey and in that capacity made two trips in the diamond district of Bahia, though none of the detailed results have been published. In April and May of 1912, in order to obtain a better idea of the geology of the Morro do Chapeo and Lençoes dis-

[1] By permission of the Director of the Brazilian Geological Survey, Rio de Janeiro.

[2] "Boletim da Secretaria da Agricultura do Estado da Bahia," Abril, 1905, pp. 217–225. Later this article was translated into English and published in Economic Geology, Vol. 1, pp. 134–142, 1905, and reproduced in the Smithsonian Report for 1906, pp. 215–222. It also appeared in the *Jornal do Commercio at Rio de Janeiro*, in May of 1905, and in the Diario da Bahia in 1905.

[3] J. C. Branner, "Outline of the Geology of the Black Diamond Region of Bahia, Brazil," Proc. Australasian Association for the Advancement of Sciences, Brisbane, 1909, pp. 324–328; "Geology of the Diamond Bearing Highland of Bahia," *Eng. and Min. Journal*, May 15 and 22, 1909; "Geology of the Serra do Mulato, State of Bahia, Brazil," *American Journal of Science*, XXX., pp. 256–263, 1910; "The Tombador Escarpment in the State of Bahia, Brazil," *American Journal of Science*, XXX., pp. 335–343, 1910; "Geology and Topography of the Serra de Jacobina, State of Bahia, Brazil," *American Journal of Science*, XXX., pp. 385–392, 1910; "The Geography of Northeastern Bahia," *Geographical Journal*, London, August and September, 1911, 139–152, 256–269; "The Estancia beds of Bahia, Sergipe, and Alagoas, Brazil," *American Journal of Science*, XXXV., pp. 619–632, June, 1913.

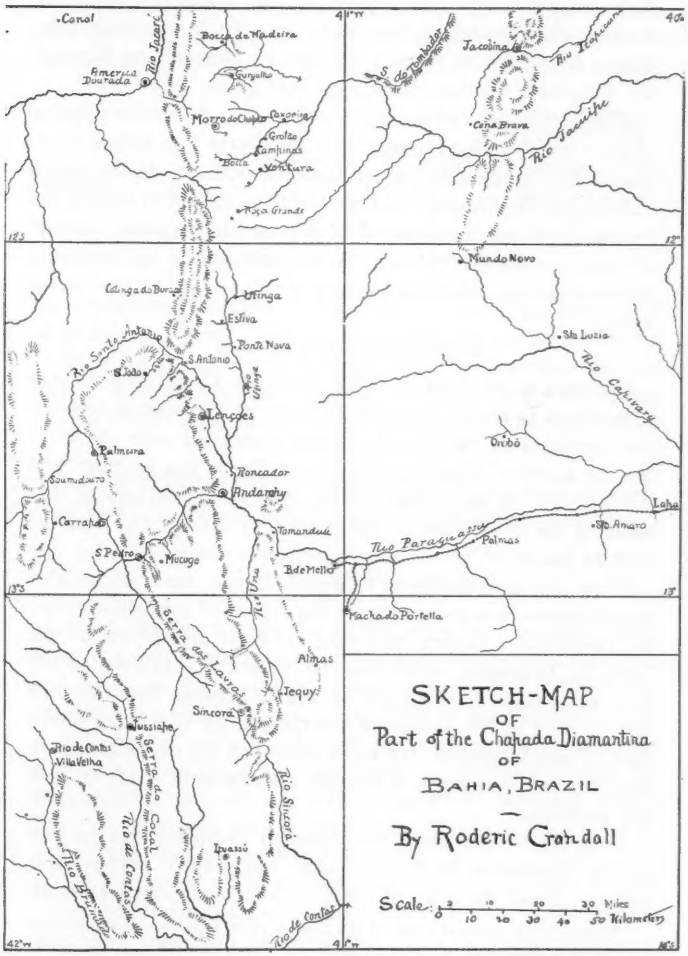

Canal
Rio Jacuipe
Rio Itapicuru
Rio Paraguassu
Rio Sincorá
Rio de Contas
Rio Preto
Rio Verde
Rio Brumado
Rio Cahivary
Rio Santo Antonio
Serra das Lavras
Serra do Cocal
Serra do Espinhaço
Mundo Novo
Jacobina
Cana Brava
Morro do Chapeo
Caxoeira
Gruta
Lamtinas
Bonfim
Ventura
Boca da Madeira
Mangabeira
America Dourada
Lagoa Grande
Lavra
Utinga
Esliva
Ponte Nova
S. Antonio
S. João
Lençoes
Palmeira
Andarahy
Roncador
Carrapato
S. Pedro
Mucugé
Tomanduá
Bde Mello
Machado Portella
Palmas
Santo Amaro
Lahe
Oricó
Ste Luzia
Almas
Tequy
Sincorá
Mussiahe
Rio de Contas Villa Velha
Ipuassú
Rio de Contas
SKETCH-MAP
OF
Part of the Chapada Diamantina
OF
BAHIA, BRAZIL
By Roderic Crandall
Scale: 5 0 10 20 30 40 50 Miles
10 0 10 20 30 40 50 Kilometers

FIG. 23.

tricts, and to study certain questions that had arisen regarding the geological sections at these two places, a trip was made from Morro do Chapeo to Sincorá, by way of Lençoes and Mucugé, and the more important results are here given.

The chief objects of the trip were, first: to determine whether or not the series near Mucugé[4] that Mr. Derby had named Paraguassú was independent of or identical with the series named Caboclo by Dr. Branner, that was first recognized by him in the region north and northeast of Morro do Chapeo; and, second: to determine the vertical range of the diamonds in the overlying diamond-bearing sandstones, which Mr. Derby called the Lavras series.

MORRO DO CHAPEO DISTRICT.

Entrance to the District.—The Morro do Chapeo district was approached from the town of Jacobina at the contact between the quartzites of the Jacobina series correlated with the iron-bearing series of Minas Geraes by both Derby and Branner, and the complex of crystalline schists, gneisses, and granites that make up the larger part of the interior, or catinga plains of the state of Bahia.

From Jacobina southwest to Brejo Grande, for a distance of 29 kilometers, is a comparatively flat region of crystalline rocks, but from Brejo Grande westward rises the escarpment of the Serra do Tombador which must be crossed to reach the Morro do Chapeo plateau. Through the region between Brejo Grande and the foot of the Tombador escarpment, 25 kilometers southwest of this settlement, the rocks belong to the crystalline complex, but the topography is rougher than between Brejo Grande and Jacobina.

Along the road, between the hamlet of Palmeiras and the foot of the Tombador bluff, a peculiar topographic feature was noticed. From the edge of the Tombador escarpment approxi-

[4] Mucugé is the original name of the mining camp from which the present city, officially christened at different times as "Santa Isabel" and "São João do Paraguassú" was evolved. To avoid confusion the old name, still current among the miners, is here used.

mately 800 meters above the normal crystalline complex plain near Jacobina, five distinct topographic features were observed in the following order from top to bottom: first, the sandstone

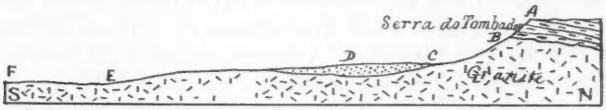


FIG. 24. Section showing the recent sediments *C–D* at the base of the Serra do Tombador southwest of Jacobina.

escarpment itself marked *A–B* on Fig. 24; second, the steep-sided slope below this, *B–C*, partly a talus slope but mainly crystalline rocks; third, almost flat table lands or taboleiros as they are here called, of a fine soft clay soil some 15 meters in thickness, and resting on the crystaline complex, *C–D;* fourth, the rounded or

FIG. 25. Recent sediments capping the table lands at the base of the Serra do Tombador.

matured complex topography of the crystalline complex, *D–E*, from which the soil cap of *C–D* appears to have been removed; and fifth, the flat crystalline complex plain, *E–F*. When one crosses these taboleiros, along the foot of the Serra do Tombador, parallel to the escarpment, the section is that shown in Fig. 25. From the top of the Serra do Tombador, these flat tablelands of soft soils are seen to extend to the south, and to form the flat-topped area covered by the Mattos do Mundo Novo, and perhaps the Mattos do Orobó also.

The two trips made through this region, one from Monte Alegre to Morro do Chapeo some years ago, and the one made in 1912, did not afford sufficient data for a satisfactory explanation of these phenomena. It is suggested that perhaps at some recent time the amount of detritus brought down from the Serra

do Tombador was greater than it is at present, and that the stream draining the area to the west of the Serra de Jacobina did not have sufficient grade to carry off all this sediment, so that a layer of silts was deposited on top of the crystalline complex, perhaps even in a lake lying between the Serra de Jacobina and the Serra do Tombador. A more recent, but slight rejuvenation of the streams has enabled them to cut through this soft cap and erode the crystalline rocks underneath, so that in their head waters they are now running in valleys 30 meters below the taboleiro tops.

The small streams that head on the east face of the Serra do Tombador, have cut narrow gulches and have a steep grade. As soon as they enter the taboleiro capping, their valleys are of the shape one sees in land-slide topography, or such as is found in the soft beds along the Alagoas coast. No definite bedding planes were seen in this soil cap. It is easy to understand how an immense alluvial fan, with a general gradient to the southeast, might easily have been formed along the foot of the Serra do Tombador, but evidence is lacking to show whether or not this soil is part of a series of old lake beds.

By a process of aggradation the present valley of the Rio Geni papo, southwest of Jacobina, is gradually becoming a wide flat valley of silts, through which the streams run with very little grade. From Jacobina down stream, through the serra and on to the southeast, Rio Genipapo has a steeper grade.

From Serra do Tombador to Morro do Chapeo.—From the eastern foot of the Serra do Tombador, at 680 meters, the ascent was made to the crest at 875 meters. The lower part of the slope up to the elevation of 815 meters is composed of the crystalline complex, and the upper part of a hard quartzitic sandstone, which has been appropriately named the Tombador series by Dr. Branner from the name of this mountain range. The beds of the series are mostly hard vitreous quartzites, but fairly soft, pink and cream colored, thinly bedded sandstones also occur. A certain amount of false bedding was observed, the inclination of the false beds generally being to the north. The true bedding here shows a dip of from 5 to 10 degrees N. 20° W.

From the crest of the Tombador, the descent was made to the broad valley of the Rio Jacuipe, here enclosed between the Serra do Tombador and the escarped margin of the Morro do Chapeo plateau, a minor valley being crossed on the road (Rio Mecca?).

Between the crest of the Serra do Tombador and the Rio Mecca, as well as between this river and the Rio Jacuipe, the Tombador series is overlain, apparently conformably, by a series of white and blue banded flints. These Dr. Branner has called the Jocuipe flints. Though the flints cover the ground for several kilometers along this road it is difficult to determine their thickness, or their precise relations to the overlying beds. Where Dr. Branner crossed these beds on the road along the Rio Jacuipe and on top of the Tombador west of Jacobina he thought they had a thickness approximating 100 meters. As far as is known at present, these flints are confined to the region near Rio Jacuipe.

The Jacuipe flints are separated from the Caboclo shale by the Rio Jacuipe bottom lands, so that the relations of the two series were not apparent, though the general dips are uniformly in the same direction.

At the foot of the escarpment which must be climbed from the valley of the Rio Jacuipe to reach the Morro do Chapeo plateau, the red shales to which Dr. Branner gave the name Caboclo, were recognized. On the ascent at 840 meters, the base of the Lavras series was observed. The basal bed here is a massive conglomerate interbedded with a white fine-grained conglomeritic sandstone, that weathers in fantastic shapes.

Well rounded pebbles mainly of sandstone and quartzite, up to 20 cm. in diameter were found. Some of the sandstones of these pebbles appears to be from the Tombador series; some small pieces of flints look like the Jacuipe flints, and through the conglomerate were many cavities from which pebbles had weathered, the shapes of these holes suggesting that they had originally held pieces of the underlying Caboclo shales.

On top of the plateau, the falls of the Rio Jacuipe, with a total drop of about 60 meters, are caused by the hard pink and white quartzitic sandstones that make up the main part of the Lavras

series, and which are similar to the sandstones interbedded with the conglomerate. The beds that form the crest of the fall are harder than those immediately underlying, giving rise to overhanging banks.

Down stream a short distance from the foot of the falls the massive conglomerate was not found, but from what could be seen from the edge of the plateau, it must cross the river a little

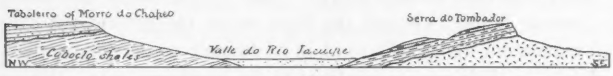


FIG. 26. Section showing the relations of the Serra do Tombador to the diamond bearing plateau southwest of Morro do Chapeo.

less than one league below the fall. This opinion was partially confirmed by the information, that just above the Fazenda Cachoeira, which is about where the conglomerate should be, there was a rich diamond washing though limited to a small area.

Small diamonds are said to be found as far down stream as Cercadinha, several leagues below the Fazenda Cachoeira.

It must be noted that the elevation of 750 meters below the falls is less than the elevation at which the diamond conglomerate was found on the line of the above section. The explanation for this appears to be that there is a sag, or slight syncline in the plateau, and that the river, where it drops off the plateau, runs through this sag.

The Region about Morro do Chapeo.—The region of Morro do Chapeo is one of high rolling prairies or "campos agrestes" as they are called in some places. The width of this region from east to west is about 50 kilometers. From the east one enters the region by crossing a monocline formed by the Tombador, Jacuipe, Caboclo, and then the Lavras or diamond bearing series; all of which dip west or northwest. The top of the highest lands east of Morro do Chapeo are not over 150 meters above the base of the Lavras series, so that it is evident that the complete section of the Lavras series is not seen, as the real thickness must be considerably greater than this.

West of the city of Morro do Chapeo is the axis of a large anticline; the beds on the east side of the city dip east by southeast, and those on the west side of the anticline dip west. The structural section through this serra is shown in the accompanying Fig. 27.

The area along the axis of the Morro do Chapeo anticline, which has a general elevation of 1,000 meters, is composed of the

FIG. 27. East-west section from the valley of Rio Jacaré showing the anticline west of Morro do Chapeo and the gentle syncline east of it.

Caboclo shales, flanked on either side by lines of hills, parallel to the axis, composed of the beds of the Lavras series. The hills on the west side are known under the local name of Serra de Martim Affonso, Serra do Boqueirão, etc., attaining elevations of 1,250 meters, with low escarpment to the east, and a more gradual dip toward the limestone catinga plains on the west.

The line of hills on the east side of the shale area begins just north of the city in the Serra do Olho d'Aguinha (1,105 m.), and continues to the northeast towards the fazendas Gurgalho and Palmeira. Apparently the east line of hills joins with the west line, some six leagues to the north of Morro do Chapeo, thus forming a semicircle open to the southwest. There are diamond washings at intervals along both these lines of hills.

Several of the more important washings in the vicinity of Morro do Chapeo were visited. Of these Boi do Chico, Gurgalho, Fonte de Cima, and Palmeira are all in the east serra. Carnahyba, Martim Affonso, and Canto are in the west serra, and all these are on the west slope. Bocca do Madeira, Carvão, and several old washings are apparently in the ridge of hills where the east and west serras join.

The washing called Boi do Chico is almost within the city of Morro do Chapeo, and the diamonds appear to have come from

thin layers of conglomerate that are here interbedded with the sandstones. Where the massive conglomerate was seen on the ascent from the Rio Jacuipe to the top of the plateau, west of fazenda Cercadinha, it is estimated to be about thirty meters thick. At Boi do Chico, the exact bottom of the series could not be seen but it is believed that these conglomerate layers are not more than 30 to 40 meters above the bottom of the series, and that the basal section here is a conglomeritic sandstone with thin layers of coarse conglomerate, rather than massive like that just mentioned.

The diamonds and carbonados at Fonte de Cima and Gurgalho and Palmeiras all come from about the same geologic horizon.

At Palmeira the Lavras series rests on the Caboclo shales, which at this point are deep brick red, quite hard, and show considerable crumpling and warping. At this point also more pieces of flints were found in the conglomerate that look like those of the Jacuipe series.

This I consider sufficient basis for stating that the unconformity between the Caboclo series and the Lavras series, though not very marked by difference in dip, is large, as is indicated by the presence of these flint fragments mingled with the sandstone pebbles, which are presumed to represent the Tombador series.

The fact that the Lavras series at Morro do Chapeo rests directly on the Caboclo shales should be borne in mind when the description of the section in the region of Lençoes and Mucugé is given.

The distribution of diamonds about Morro do Chapeo.—The diamond washings visited on the west line of the hills at Martim Affonso and Carnahyba[5] show first, that the diamonds here are smaller than in the washings in the east line of hills; second, that the conglomeritic sandstones are finer in grain; and third, that

[5] The largest carbonado found at Carnahyba is said to have weighed 11 grams or 2¾ carats, while the largest diamond was 4 grams or one carat. A single batea of concentrates is reported to have yielded as many as 200 small diamonds and carbonados.

they appear to be higher in the section than at the eastern washings. Martim Affonso and Carnahyba are old washings that have yielded many diamonds, though never very large ones.

East and southeast of Morro do Chapeo, the diamonds and carbonados are larger, the carbonados from Campinas, Rio Preto and especially from Grotão and Ventura, being very large.[6] The washings at these various places were visited and the basal conglomerate was seen to be well developed at all of them, boulders of 15 to 20 cm. in diameter being common.

Three of these washings are in the basal conglomerate, or rather they are in the rivers that receive the concentrates from the conglomerate. Grotão, Ventura and Rio Preto are all three situated on the rocks of the Caboclo shales series, but in each case the conglomerate is near the top of the plateau, while the houses and washings are along the river.

In all of the washings mentioned around Morro do Chapeo, the carbonados are much more important than the diamonds. But aside from this is a series of rocks, which in the lower part of the section is either a conglomerate, or a conglomeritic sandstone, the size of the pebbles varying from east to west, and the size of the diamonds varying directly with the coarseness of the conglomerate.

The evidence regarding the vertical distribution of the diamonds in the Morro do Chapeo district, is rather unsatisfactory. East of the town, the full section is not known, and on the west the data are insufficient. At Campinas the horizon from which the diamonds are obtained is above that from which the stones are obtained at Ventura and Grotão. As determined by an aneroid, this difference of level is 80 meters, so it is evident that the diamonds have at least this vertical range.[7]

[6] The largest carbonados from Grotão weighed 33 oitavos, about 577½ carats, and this is said to be the largest stone from the Morro do Chapeo-Ventura district. From Rio Preto the largest carbonado weighed 11 oitavos, or 192½ carats; the largest diamond weighed 14 grams, or 3½ carats.

[7] Dr. Branner is of the opinion that diamonds and carbonados found below the edge of the plateau at Ventura may come from the same beds in which they occur at Campinas on top of the plateau.

THE DISTRICT SOUTH OF MORRO DO CHAPEO.

Southward past Ventura, on the road to Lençoes, the last washings were seen at Rio Preto a league southwest of Ventura. From this point southward, the road is for the most part on top of high flat-topped ridges, partly covered with forest, and if the diamond beds exist, as they probably do, they are so unfavorably located with reference to the water required for washing that no mining has been undertaken in them.

All the valleys are cut into the Caboclo shale, so that the section from Ventura, south to Roça Grande, is as shown in Fig. 28.

The ridge between Rio Preto and Roça Grande should be

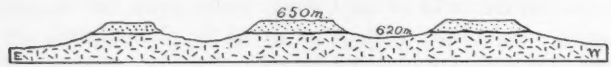


FIG. 28. Section showing the structure south of Ventura where the Caboclo shales underlie the diamond-bearing beds.

diamond bearing, and it is probable that the main reason there are no washings in it is the scarcity of water. It is also possible that diamonds found here would all be small, as the sandstones are fine grained. From Roça Grande southward to Boa Esperança ridges similar to those just mentioned were crossed, but as they are almost entirely covered with forests, it is difficult to ascertain the nature of the capping formation. This region from Rio Preto south presents a general topographic feature that differs considerably from the region north of it.

The Serra do Tombador, which begins to attain prominence northwest of Villa Nova da Rainha, extends as far south as the latitude of Ventura, with an abrupt escarpment facing southeastward. This shows the geological structure of the east side of the Salitre valley, and of its southern continuation in the plateau near Morro do Chapeo to be a large syncline.

South of Ventura, the Tombador escarpment loses its prominence as a topographic feature. Its disappearance, in part at least, is due to a change in the dip of its beds from west to east,

which carries them underneath the horizontal beds of the Estancia series, which commences to appear here. This latter series forms a low plateau with a general elevation of about 500 meters, and lies east and abuts against the higher Morro do Chapeo-Lençoes-Mucugé plateau (1,000–1,100 m.) popularly called the Chapada Diamantina. This lower plateau is imperfectly known, but it is certain that it extends southward as far as the latitude of the village of Sincorá. In a part of this extension its eastern margin presents a prominent escarpment, and in most of this area the Salitre limestone is associated with the Estancia series.

At several places on the road between Roça Grande and Utinga, the diamond bearing sandstone is to be seen, the most notable exposure being near Boa Esperança, where a small thickness of it rests on the Caboclo shales, and where a few diamonds have been found. Entering Utinga from the north a ridge of sandstone is exposed west of the road, which seems to belong to the diamond bearing series. From Utinga to Estiva and Lençoes, both famous diamond centers, the road is over the Estancia series, parallel to the Chapada Diamantina, and diamond washings are not seen except where one enters the gulches that cut the Chapada front.

In the Chapada proper, west of Utinga and Estiva, the Caboclo shale is more in evidence than any other series, the diamond bearing beds being less prominent than they are near Morro do Chapeo.

A section across the Chapada along an east-west line, passing through Utinga, shows a broad anticline, with a north-south axis, and a wide area of Caboclo shales, flanked on each side by the diamond-bearing series, and this in turn by the Estancia beds. West of the Chapada, the Estancia series, especially the Salitre limestones, are quite prominent, covering nearly all of the floor of the valley of the Rio Jacaré. It is difficult to draw a line of demarcation between the Lavras and the Estancia sandstones on the west face of the Chapada.

In the northern section of the Chapada from Morro do Chapeo

to Utinga, no positive evidence was obtained of the existence of the Paraguassú series, which is so prominent in the neighborhood of Lençoes and Mucugé. At Morro do Chapeo, the diamond series rests directly on the Caboclo shale series. At Lençoes the Caboclo shale and the diamond series are separated by 350 to 500 meters of sandstone, to which Derby has given the name of Paraguassú series. From Morro do Chapeo south to Utinga, and on the west side of the serra, as well as on the road from Utinga to Catinga do Buraco, the Paraguassú series was not observed; it must begin between Utinga and Lençoes, probably near Estiva.

At Utinga no diamonds have been found, but near there, at Cachoeirinha, some small stones have been washed. At Estiva carbonados of good size are washed, and some of the largest and best diamonds of the Lençoes region are found there (up to 22.5 carats).

The best diamond and carbonado section of Bahia is said to be that extending from Estiva southeast to the south of the city of Mucugé. The diamonds from this district are said to be larger and better than those of the Morro do Chapeo district, or from the Chapada Velha washings. The carbonados are larger than from either of the other districts, with the exception perhaps of those coming from Ventura, which are also quite large.

THE LENÇOES DISTRICT.

In several trips in the vicinity of Lençoes, additional information was obtained regarding the vertical range of the diamonds in the Lavras series. The thickness of this series is estimated at from 300 to 250 meters as follows and in their natural order:

THE LAVRAS SERIES AT LENÇOES.

		Meters.
Top:	Pink sandstone weathering to white sand	75–125
	Red, white, and blue shales	20
	Pink quartzitic sandstone	50
	Red shale with sandstone and fine conglomerate	10
	Coarse conglomerate with interbedded sandstone	40
Bottom:	Massive conglomerate	5
	Total	200–250

The massive conglomerate at the bottom of this series is the bed that furnishes the most important washings on the slope of the Serra das Lavras, and is especially well developed around Barro Branco. Here, and also at Veneno, another important washing south of the town, the workings are in decomposed portions of the lower conglomerate. These washings are on the slope of the mountain west of Lençoes and near the top, that is where the beds of the diamond series lap over on the underlying Paraguassú series which forms the main mass of the mountain.

From the city of Lençoes southward or down Rio São José, there is an old series of washings, along the foot of the Serra das Lavras, Lavradio, Mosquito, etc. These have all been rich washings, and have been worked down to bed rock which is the 20 meters of blue, white, and red shales mentioned above. It is evident that the stones washed here came from the diamond-bearing bed above the shales, and, therefore at least 125 meters above the bottom of the series.

Just how far upward the diamonds extend, is not definitely known, for there are no washings in the top section of the diamond series east of Rio São José, possibly for lack of water. I was told at Lençoes that one large stone had been found in the white sands along the road from Lençoes to Sto. Antonio da Cravada. This suggests that diamonds occur higher in the series than those of the Mosquito and other washings in the bottom of the valley of the Rio São José. As the upper section of the Lavras series is mainly composed of fine sandstone, the plausible rule that the size of the diamonds is proportional to the coarseness of the rock in which it occurs, suggests that the upper part of this series is relatively unimportant commercially.

Since the diamonds extend through about half of the Lavras series, and as there is no definite break between the upper and the lower parts, it seems reasonable to assume that the whole series may be diamond bearing.

Fig. 29 shows the structure of the Serra das Lavras, from the river Sto. Antonio northwestward to the campos beyond São João, in which the Estancia and Salitre beds appear. This is in

effect a section across the chapada at this point, and comparing it with the one given above for the region of Morro do Chapeo, the following important tectonic and geological differences are to be noted: the broad anticlinal swell, which in the northern section constitutes the western and central parts of the chapada,

FIG. 29. Section across the Serra das Lavras anticline. The diamond-bearing series rests unconformably against the Paraguassú beds.

is here greatly narrowed, and its character as a breached anticline becomes accentuated; the syncline to the east, whose eastern escarpment forms the Serra do Tombador, has disappeared and also the Tombador sandstone, its function of a resistant bed giving ruggedness to the eastern front of the chapada being taken by the Lavras series (apparently with a thickness considerably in excess of that presented in the Morro do Chapeo-Ventura district) and its accompanying Paraguassú series, which is also of a resistant character.

From the city of Lençoes, a trip was made to Mucugé by way of Capão Grande, along the west side of the Serra das Lavras. From the Serra das Lavras, and from the trip made to Mosquito, it could be seen that the chapada is here an anticline, the Lençoes side dipping to the east. All along the face of this slope, from Lençoes to south of the city of Andarahy, the diamond conglomerate rests on the Paraguassú sandstones, in such a way that a large amount of it is exposed to weathering, thus furnishing the many important washings in this part of the diamond district.

On the roads from Lençoes to Capão Grande and to São João, the unconformity that separates the diamond series from the underlying Paraguassú sandstones is visible at several places. The principal pebbles here are of flaggy sandstone from some underlying series, slightly water-worn, and ranging in size up to 50 cm., and much water-worn white quartz and quartzitic pebbles. Only a few pebbles were seen that could be referred to the

Paraguassú series, and Mr. Derby informed me that this is in accordance with his own observations in the parts of the Lençoes, Andarahy and Mucugé districts traversed by him.

At Lençoes there is a plainly marked unconformity between the diamond series and the underlying beds. At Morro do Chapeo, the whole Paraguassú is missing, due either to its erosion or to its never having been deposited; the latter seems to be the more plausible explanation. The Paraguassú beds do appear, however, in the Chapada Velha district, west of the Morro do Chapeo area. Such being the case, a section such as Fig. 30

FIG. 30. Hypothetical section from near Morro do Chapeo to Chapada Velha showing why the Paraguassú beds appear at the latter place but not at the former.

will explain the absence of the Paraguassú beds from Morro do Chapeo, on the hypothesis that the shore line of this series did not extend so far eastward.

From Lençoes to Mucugé.—The section from Lençoes to São João, the wets side of the anticline swings to the west, the strike changes from N–S with west dips, to E–W with north dips, forming the Serra do Olho d'Agua. West of Palmeiras, the structure becomes more complicated, the folding is steeper, and there is considerable faulting.

This Serra do Olho d'Agua presents an escarpment facing southward, and is a north dipping monocline, and the main Serra das Lavras, from the Serra do Olho d'Agua south, presents an escarpment facing the west and is an east dipping monocline. This monocline of the Serra das Lavras, with its escarpment, extends from approximately the latitude of the city of Lençoes to the south of Sincorá, perhaps 25 kilometers. With a total length of about 120 kilometers, it is the most salient topographic form in the state of Bahia.

The western face of the Serra das Lavras is for the most part a fault escarpment, though this does not mean that the west side of the fault has been dropped down abruptly far enough to form this face as it appears at the present time. The faulting along the west face of this escarpment is probably not more than 200 meters, if so much. This fault is approximately the axis of an immense anticlinal fold by which the Serra das Lavras arched to the serra west of the village of Carapato. In the bottom of the Rio Preto fault valley, the diamond conglomerate is undisturbed and the section through the Serra near Capão Grande is shown schematically in Fig. 31. The whole block of sandstone

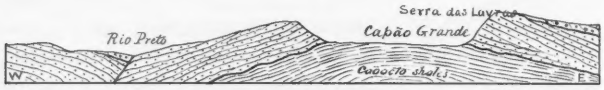


FIG. 31. East-west section across the Serra das Lavras near Capão Grande showing the anticline and the Rio Preto fault.

forming the dome of the anticline and lying between the present Serra das Lavras and the serras west of Carapato, has been eroded away.

Between these two serras is an immense flat region of Caboclo shales in which the Rio Paraguassú heads. This plain is crossed by the road from Capão Grande to Mucugé, and from Mucugé to Jussiape, and again from Jussiape to Sincorá. Owing to the softness of the shales of the Caboclo series and to their low dip, this is a region of low relief, and there are but few outcrops of the underlying rocks.

The general elevation of this plain above sea level is from 1,000 to 1,200 meters, and it is protected from erosion on the north and east sides by the Serra do Olho d'Agua and the Serra das Lavras, and on the west and south by the rocks of the Tombador series. Fronting the escarpment of the Serra das Lavras along its eastern border, picturesque block-like outliers of the Paraguassú series are abundant.

From Capão Grande to Mucugé, after one passes out of the

Serra do Olho d'Agua four leagues south of the hamlet, the road is parallel to the steep face of the Serra das Lavras accompanying it to the point where the Rio Paraguassú cuts this serra. The river has cut more rapidly in the shales of its upper course than in the sandstones of the Paraguassú series in the serra, so that at the point where it enters the serra there is an aggraded area, with lakes and swamps, and where the river enters the sandstones there are falls and rapids. The topography of the Serra das Lavras is characterized by many large wind gaps.

Where the Rio Paraguassú enters and cuts the Serra das Lavras, the general section is that shown in Fig. 32, the fault on the

FIG. 32. East-west sections showing the relations of the Tombador, Caboclo, and Lavras beds to the topographic relief.

west side being entirely in the Caboclo shales and is shown only by a slight change in dip.

From Mucugé to Jussiape.—From Mucugé to Jussiape, the shale plain is crossed, the western edge of it overlooking the valley of the Rio Jussiape at an elevation of about 1,250 meters. This edge is the Serra do Cocal, and Fig. 32 shows the drop from this plain to the valley. From what could be seen from the western edge of this shale plain, or the top of the Serra do Cocal, the Jussiape valley seems to be a big anticline, with some faulting parallel to the axis of the fold.

From the elevation of 1,250 meters, the descent is abrupt, through about 400 meters of Tombador sandstone, and in the descent, two small faults are crossed, which give a series of step or block faults dropped down to the west. From the topography an assumed ideal section across the Jussiape valley is shown in Fig. 33.

Going up the escarpment again from the granite valley of the

Jussiape on another road, this same step faulting was crossed, and it was noted that there were lines of granitic hills, which seem to be parallel to the structural lines of the folds and faults.

The top of the mountain between Jussiape to Sincorá is composed of Tombador sandstone, though the Caboclo shale laps well up on it. The Tombador here is arched very slightly in an

FIG. 33. Section across the valley of Rio Jussiape showing the structure suggested by the topography.

anticline,, with an east and west axis, dipping north from five to ten degrees under the Caboclo shale, or the flat valley of the upper Rio Paraguassú. Thus the western limit of this flat valley is in the east dipping Tombador sandstone, and the southern limit is in the same rock dipping north. Where the dip changes to the south, the water drains to the Rio de Contas. Near Sincorá this anticline disappears, and the Tombador dips east again, forming the lower part of the serra on the west side.

Two points of special interest were noticed on top of the water divide west of Sincorá. The first was that the Jacobina, or Minas, series is near the west edge of the escarpment, there being a small deposit of good grade iron ore (hematite) at one place. The Minas series here dips west, while the Tombador at this particular point dips east, and the unconformity between the two is plainly seen, as well as the difference in the degree of metamorphism of the two rocks. The sandstone accompanying the iron ore shows considerable metamorphism, while the Tombador shows crushing only, and that in limited areas. The second feature of note was the large number of quartz veins in the Tombodar sandstone along the water divide, some of which may be gold bearing.

At Sincorá, the section through the serra is the same as further north, except that the Serra do Sincorá north of the village, is composed mainly of Caboclo shales and Paraguassú beds, the

diamond series being entirely eroded away. It is said that a few diamonds were found a good many years ago on the top of this serra.

Fig. 34 is generalized on an east west line along the watershed

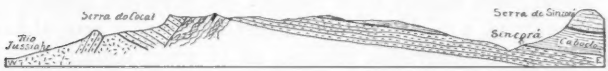


FIG. 34. Section from Rio Jussiape to Sincorá to the Caboclo shales and the Tombador sandstones beneath.

dividing the waters of the Rio Paraguassú from those of the Rio de Contas, and is mainly in the Tombador sandstone, with the strike of these beds parallel to the section. Fig. 35 is an ideal section, taken at right angles to the first, or along a north

FIG. 35. North-south section showing the structure about the headwaters of the Rio Paraguassú.

and south line, showing the relation of the Tombador to the Caboclo shales.

THE SINCORÁ SECTION.

The village of Sincorá is in the upper part, or almost at the top of the Tombador, so that two kilometers east of the town are the best exposures of the Caboclo shale that have been seen. The thickness is estimated at about 350 meters. At this point the thickness of the Paraguassú beds was also estimated at about 2550 meters, which is considerably less than in the Mucugé section, further to the north.

At the gap in Serra das Lavras near Sincorá are the Paraguassú beds. Isolated peaks of the Paraguassú beds rise several hundred meters above the level of the gap, the dip being to the east. From this point, some faulting in the Paraguassú beds is visible, the downthrow being to the east. From the top

of the serra, the descent to the east is abrupt, down an escarpment that dips east, and is mainly composed of Paraguassú sandstones.

THE UNA FAULT.

About three leagues from Sincorá one notes the absence of rock outcrops, a marked change in vegetation, and a general flattening of the topographic features, all of which indicate a passage to a different geological formation, the character of which is not immediately apparent.

At the crossing of Rio Una, between Jequy and Sincorá, pieces of chert were found, which were recognized as part of the series of Estancia shales and sandstones, or perhaps rather of the Salitre limestone, which served to identify the series that covers the region east of Campo do Meio.

Looking westward from this point, it can be seen that the Serra das Lavras is faulted down on the east side, in one large fault, with many small ones in the serra parallel to the main one, in such a way that the Estancia shales with the accompanying Salitre limestone are brought in contact with the Paraguassú beds, as shown in Fig. 36. A section drawn through Campo do

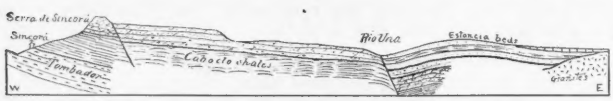


FIG. 36. Section from Sincorá showing the Una fault and the relation of the Estancia beds to the granites.

Meio, with the assumption of 300 meters of the Estancia beds, 250 meters of the Lavras series, 250 meters of the Paraguassú series, and 350 meters for the Caboclo series, requires a total downthrow of 700 meters or more, to account for the relative positions of the beds.

South of the road from Jequy to Sincorá, the topography suggests that the Estancia beds on the east rest against the Caboclo shales on the west side of the fault, though this was not verified by actual observation.

The extent of this Rio Una fault is not known. The topography indicates that the throw grows greater to the south, and that it dies away toward the north. On the road between Bebedouro and Mucugé there is a small anticline at Rio Piabas which dies away to the north and increases to the south, and it seems probable that this is the northern end of the Rio Una fault.

The approximate throw of this fault must be from 500 to 600 meters, while the total downthrow on the east is increased by various small step faults in the serra proper, the largest of which must be about 150 meters vertically.

From Jequy to Almas, the road is on the Estancia series, and the Salitre limestone caps the hills east of the road. This, then, would be the southern continuation of the limestone near Bebedouro and on the Rio Una on the road leading from Bandeira de Mello to Andarahy.

Two kilometers northeast of Almas, the road comes into the granites and crystalline complex at an elevation of 675 meters, or much higher than the elevation of 550 meters, where the Estancia beds were first encountered. Evidently the crystalline complex formed a line of hills to the east, which limited deposition in that direction.

RÉSUMÉ.

A review of the geological column of the Chapada Diamantina of Bahia gives the following series of beds from the bottom upward.

The Crystalline Complex is composed of banded gneisses and crystalline schists with granites, apparently of more than one age, some of which are intruded in the general complex.

The Jacobina Series (1,000 m.).—Next is the Jacobina series of quartzites, vitrified sandstones and metamorphosed shales, which are best represented in the Serra de Jacobina. These are provisionally considered to be the same as the iron-bearing series of the state of Minas Geraes and which is well exposed in the vicinity of Ouro Preto, and thence northward toward Diamantina. This series of rocks rests on the crystalline complex in Bahia, though its relations to the granites are not yet apparent.

Dr. Branner has stated, in his paper on the Serra de Jacobina, that the basal conglomerate, where it was seen by him showed no granite boulders; the writer has made the same observation.

The Tombador Series (400 to 500 m.).—Resting unconformably on the Jacobina series is the Tombador quartzitic sandstone, best exemplified in the Serra do Tombador west of Jacobina, or in the Serra do Cocal near Jussiape. The most typical rock of the Tombador in a locality where it is exposed to a dry climate, is a hard vitrified rock, weathering to a smooth finish on the outside, though much of the series is of a softer cream-colored sandstone, that weathers more rapidly and is therefore less prominent in the topography. The Tombador sandstone wherever it occurs in the more arid regions forms abrupt escarpments, and a rugged topography. It is not generally conglomeritic, at least in its basal portion, though from the observations of Dr. Branner in the Serra do Mulato, conglomerates appear in its middle or upper portions.

The Jacuipe Flints.—The Jacuipe flints described from the region to the east of Morro do Chapeo are not given here as a series, because from their local appearance, and from the presence of layers of a somewhat similar bed in the Lavras series near Lençoes, they are considered as being more probably the lower part of the Caboclo shales as Dr. Branner has already pointed out,[8] rather than an independent series. The thickness, however, where best developed, is about 100 meters.

The Caboclo Shales (500 m.).—Above the Tombador sandstone in the sections near Morro do Chapeo, and in those of the Serra das Lavras near Sincorá, is the Caboclo shale, which as far as present knowledge goes, is conformable or approximately conformable in dip with the Tombador sandstone.

The shales are brown, deep red, and gray, with greens, yellows, pinks, and lavenders in places. The series apparently has some soft yellow sandstone layers in it as is shown by the character of the soil in various places. At Morro do Chapeo the top bed is a red shale that shows some effects of pressure and movement

[8] *Amer. Jour. Sci.*, XXI., 481. June, 1911.

absent in the overlying sandstones. Near Sincorá, the series was estimated at 350 meters, though Dr. Branner gives 500 meters for the same series near its type locality in the Jacobina Nova district north of Morro do Chapeo.

The Paraguassú Series (500 m.).—Where the Paraguassú series has been seen overlying the Caboclo sandstone, it is conformable in dip, and the change is from shale to sandstone, without any conglomerate. The Paraguassú series is argillaceous sandstones, and shales, reddish, yellow or cream colored, and fairly uniform throughout the whole section.

On the Rio Paraguassú, near Mucugé, which is the type locality, this series attains an approximate thickness of 500 meters.

The Lavras Series (250 m.).—The Lavras series is composed of a thick basal conglomerate and hard pink sandstones that are conglomeritic in places, and often false-bedded. The great mapority of the pebbles are of sandstone more similar to that of the Tombador series than to any other known in the region. At the Veneno diamond washing near Lençoes, Derby noted large boulders of the underlying Paraguassú sandstone and of an eruptive rock not otherwise known in the region. In the Lençoes region the unconformity between the Paraguassú series and the Lavras is plainly visible.

In the Morro do Chapeo region the Paraguassú is lacking, the Lavras resting on the Caboclo shale, and the pebbles of the conglomerate indicating that the unconformity here is large, and suggests the uplift an derosion of the series.

The beds of the Lavras series seem to vary somewhat from place to place; the detailed section for Lençoes is given in this article; wherever it appears it is prominent in the topography, because of the hardness of the basal conglomerate, and the fantastic shapes into which the sandstone weathers.

The Estancia Series (350 m.).—The type locality of the Estancia series is in the state of Sergipe, but it is well represented in Bahia, being well exposed along the eastern border of the Serra das Lavras and west of Orobó. The series is composed of red sandstones and shales interbedded, a distinctive feature

of these beds being the chert nodules that are scattered through the limestones. In some sections, such as the one west of Bandeira de Mello, there are long stretches of road covered with these weathered out chert nodules. The actual contact between the Lavras series and the overlying Estancia series is difficult to find, but in the general geology of the district it is clear that the Lavras series was folded prior to the deposition of the Estancia beds.[9]

The Salitre Series (450 m.).—This series of limestones is named from the Salitre valley, where it covers nearly all the valley floor, as it does likewise in the valley of the Rio Jacaré. It is a fine-grained limestone, generally blue though in some localities white, pink, or gray. It is metamorphosed in a few localities, so that it has become marble. As far as is now known, the Salitre rest conformably on the underlying Estancia series.

The latest formations in the area described are the river gravels, the lake deposits, and the secondary limestone deposits, such as are found south of Joazeiro and in the Salitre valley.[10]

[9] Fossils recently found near Aracy, Bahia, show these beds to be Permian. "The Estancia Beds of Bahia, Sergipe and Alagoas, Brazil," by J. C. Branner, *Am. Jour. Sci.*, XXXV., 619–632, June, 1913.

[10] J. C. Branner, "Aggraded Limestone Plains of the Interior of Bahia, etc.," *Bull. Geol. Soc. Amer.*, XXII., 187–206, 1911.

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COMPILED BY HAROLD L. WHEELER.[1]

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DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

GRAPHIC DETERMINATION OF DIP COMPONENTS WHERE DIPS ARE MEASURED IN FEET PER MILE.[1]

Sir: I am sending herewith a series of curves, plotted on coordinates, which may be used to find the inclination of a stratum, or of any relatively flat surface or layer, in directions not perpendicular to strike, when dips are low and are recorded in *feet per mile*. It has proved to be of some value in determinations of convergence and in other problems arising in petroleum geology.

The use of the diagram may be illustrated as follows: Suppose that the strata dip 50 ft. per mile due north and that we want to find their inclination in the direction N. 30° E. The latter inclination may be referred to as the dip component in this direction. The horizontal angle between the true dip and the dip component is here 30 degrees. Find the point on Fig. 37 where the vertical line labeled "30°" (top of Fig.) intersects the horizontal line marked "50 ft." (left of Fig.). This point is between two curves which, if followed up to the left margin of the figure, will be seen to be marked "40 ft." and "50 ft.," respectively. Since the point in question lies about one third way from the 40-foot to the 50-foot curve, the required dip component is found to be between 43 and 44 feet per mile in the direction N. 30° E.

In like manner, the true dip may be obtained from a known dip component, thus: Let the strike of the beds be N. 10° W.

[1] This article was printed in the last number of the Journal with a paragraph transposed. It is here reprinted in corrected form and is meant to entirely replace pages 176–178 of this volume.—*Editor.*

and suppose that two well logs show that these beds are inclined 30 feet per mile in a direction N. 40° E. The true dip is in the direction N. 80° E. The angle between the direction of the true

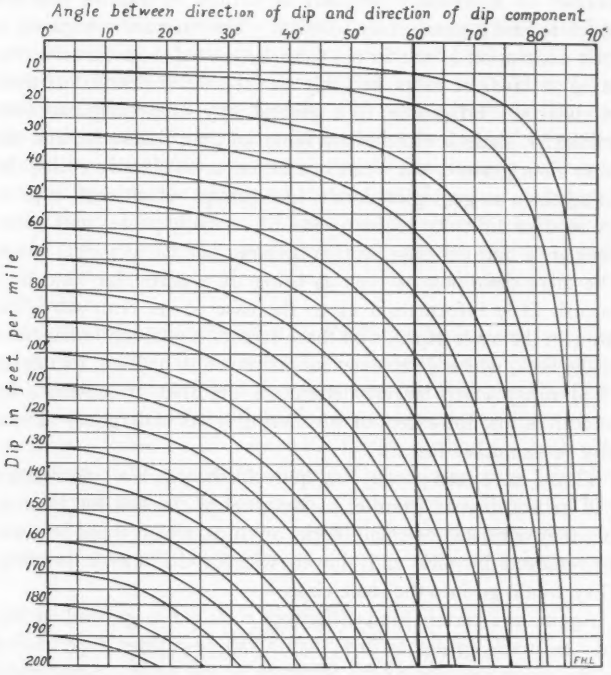
Angle between direction of dip and direction of dip component
0° 10° 20° 30° 40° 50° 60° 70° 80° 90°
Dip in feet per mile
10' 20' 30' 40' 50' 60' 70' 80' 90' 100' 110' 120' 130' 140' 150' 160' 170' 180' 190' 200'
FHL

FIG. 37.

dip and the direction of the dip component is 40°. On the diagram find the point where the vertical line marked "40°" intersects the curve marked "30 ft." This is approximately on the horizontal line marked "40 ft.," indicating that the required true dip is about 40 feet per mile.

Observe that, in all cases, the horizontal lines are for true dips and the curves are for dip components.

FREDERIC H. LAHEE.

ROCK CLASSIFICATION FOR ENGINEERING.

Sir:—The problem raised by Prof. W. D. Smith in the last number of ECONOMIC GEOLOGY is I think a difficult one for which to find a satisfactory solution. The contractor engaged in rock excavation is not in the least interested in a classification based on *kinds* of rocks, but only on the ease of removal of them as material. Of course, in a general way, one recognizes that, ordinarily, shale is more easily removed than limestone, and the latter than granite, but when one attempts to classify rocks, defining them as geological kinds, into groups which shall express the relative difficulty of their removal, so many phases and variations arise that the classification becomes of little practical value. The mere definition of rock as being of a particular kind may furnish little information as to the ease of its removal. The latter in the main depends on three factors, the absolute hardness of the rock, which determines its resistance to drilling, its degree of jointing, which largely determines the area of loosening by explosives, and the extent of weathering it has undergone. There may be also other factors.

Thus I have seen porphyries, quite fresh, which would resist a drill as sturdily as granite, so thoroughly checked by jointing that they consisted of small blocks or chips, which could be readily removed by pick and shovel, without drilling or blasting. They would go into the shale class.

Again, of a certain kind of igneous rock, a fine-grained variety may be much harder to drill than a coarse-grained type, owing to the easier cleavage of the feldspars in the latter. Some rocks drill easily but deaden the effect of blasting. The amount of alteration, whether by hydrothermal processes or by ordinary weathering, is a very decisive factor in many cases, but, as Professor Smith points out, a very difficult one to obtain agreement on.

It appears to me then hardly practicable to obtain a classification of the nature indicated, which would serve as a basis for contracts without reference to the actual material itself. But if

the material itself is examined the classification will be of little service; if it cannot, in the nature of things, be foreseen what its character will be, the contractor will naturally insist on such terms as will insure him against all contingencies.

As for engineers who are obliged to use some sort of classification, in making reports on work to be undertaken, I must refer them to "Rocks and Rock Minerals," since the tables there given represent the best I could devise for such purposes. But the terms there used for rocks, to attain full value, should be accompanied by descriptive matter relating to the fineness or coarseness of texture, the nature of the cement if present, the degree and extent of jointing or rifting, and the amount of alteration if any. From such data an experienced engineer ought to obtain a fair idea of the task of working such material and of the costs involved.

On the whole, as suggested by Professor Smith, the best plan, when the extent of the work to be undertaken is considerable enough to warrant it, is to have the area involved examined by a geologist or engineer with sufficient geological training and experience. Based on his report the fairest method for both sides is to then make a tentative contract, which may vary according to different conditions met with. This may be illustrated by a simple case from my own experience. A number of years ago a water company desired to pass a tunnel through a high inter-

FIG. 38.

vening ridge and take water from a stream into a lake used as a storage reservoir. The conditions are shown in Fig. 38. The contractor, after examining the ridge on both sides decided that the tunnel would be driven entirely in trap rock and his estimate of charges was based accordingly. The water company did not agree with this, and I was called in consultation. After study of

the section shown in the figure, and examination of the sandstone of the region, the contractor agreed to a tentative contract, so much per foot in sandstone, so much in trap, and both parties were satisfied with the arrangement.

Is not the proposed classification summed up by simply saying, "hard rock," "ordinary rock," "soft rock," and "earth"?

LOUIS V. PIRSSON.

REVIEWS

The Barite Deposits of Missouri and the Geology of the Barite District. By WILLIAM ARTHUR TARR. The University of Missouri Studies, Vol. III., No. 1, published by the University of Missouri, Columbia, Missouri.

This royal octavo report of 111 pages of text and ten plates is a comprehensive report on the barite deposits of Missouri, about half of the volume being devoted to the topography and geology of the area and the other half to the mineral deposits.

The deposits occur in two districts, the Washington County district, including also part of the adjacent St. Francois County, in the eastern part of the state, and the central district, comprising parts of Moniteau, Morgan, Camden, Miller and Cole counties. The former is the more important and is discussed in detail. Only a brief description of the geology of the central district is given, unaccompanied by a map.

The formations with which the deposits are associated are rather fully described and the distribution of their outcrops in the Washintgon County district is shown on a colored map. The barite deposits in this district are associated with the upper part of the Potosi formation and the overlying Proctor formation, both of which are dolomite containing considerable chert, especially a bed at the contact of the two which may possibly represent the Eminence formation. In the central district the barite is associated with the Gasconade, Roubidoux and Jefferson City formations.

The barite is described as of four types: (*a*) veins, (*b*) disseminated deposits, (*c*) cave deposits, and (*d*) residual deposits. The veins are mostly small and are closely associated with the so-called disseminated deposits, which are described as irregular masses in the dolomite. The cave deposits are in solution caves in the Potosi and Proctor dolomite. The residual deposits, the most important type from the commercial point of view, are derived from the other three by weathering and concentration of the insoluble barite in the residual red clay. In the unweathered deposits the barite is associated with several other minerals, deposited in the following order: quartz, pyrite and marcasite, galena

and sphalerite, barite. The barite being last to be deposited generally covers the other minerals.

The author states that most geologists hold the view that the barite in this, as well as in most other areas of the country where the mineral is associated with limestone beds, was deposited by descending waters which had dissolved the barium from disseminated minerals in the associated sedimentary rocks. He points out, however, that most limestones carry very little, if any, barium compounds and analyses of samples from the Washington County district showed not a trace of barium. After further discussing the mode of origin the author concludes that the barite and associated minerals in the Missouri deposits were derived from rising solutions from a deep source, presumably igneous rock.

The reviewer is not convinced by the arguments presented of the correctness of this interpretation. The fact that the deposits lie mostly along the contact of the Potosi and Proctor dolomite, or just below it, at the horizon of the supposed Eminence chert, which is either absent or greatly thinned in this area, suggests to the reviewer that the barite was probably originally deposited in somewhat disseminated form at the unconformable contact of the Potosi and Proctor formations and, like certain other deposits (such as manganese and phosphate) and certain minerals (such as glauconite) which are not widely distributed in sedimentary rocks, seems to have been accumulated on an old land surface during the process of weathering and to have been incorporated in the first sediment of the succeeding Proctor formation. Before the newly proposed theory of the origin is accepted samples of the basal beds of the Proctor formation and cherty beds of the so-called Eminence should be analyzed for barium.

From bookmaking and service points of view there are several marked defects in the volume. The absence of the date of publication is the first noticeable omission. The entire absence of text figures is to be lamented. A key map is very much needed to aid the reader in understanding the scope of the paper and the general location of the two districts. A graphic columnar section and simple sketches illustrating details are also a help to any such publication. The ten halftone cuts, placed probably for economy at the end of the report instead of within it where they would be more serviceable, have no titles and the reader must refer back to the list of illustrations at the beginning of the report. The map of the Washington County district, forming folded Plate I., although printed in colors, lacks character and clearness by reason of the uniform density of the patterns. To have produced the desired contrast the pattern lines should have been of different strength and spacing as well as of direction. The boundaries between formations would

better have been printed in black dotted lines with the contours, as misregister of the colors makes their location indefinite where the colors overlap and inaccurate at many other places.

The report on the whole is a contribution both to the subject of barite and to the geology of eastern Missouri and as such will be a welcome addition to geologic literature.

GEO. W. STONE.

ABSTRACTS

The Geology of the East Pool Mine. By MALCOLM MACLAREN. Mining Magazine, London, Vol. XVII., p. 245, 1917.

The oldest rocks are slates (killas) of Ordivician age, intruded by sills of greenstone (probably of Carboniferous age). This series is intruded by a tourmaline-muscovite-biotite-granite along which the slates show evidence of contact-metamorphism and this granite is regarded as of post-Carboniferous age. There are also dikes of granite-porphyry (elvans) in the slates. Latest of all are mineral-bearing lodes, which are regarded as the product of emanations from the granite magma. These lodes are not definitely described as to their petrographic character. A plan map and vertical section of the lodes is given, showing a complex of nine lodes dipping northerly at angles of from 29° to 75° and four lodes dipping southerly at angles from 70° to 80°. The deepest working is on the New North lode, depth 2,058 ft.

The most important economic minerals of the East Pool lodes are as follows: Cassiterite, wolframite, chalcopyrite, arsenopyrite, bismuthinite, azurite, stannite, scheelite, fluorite and some cobalt ore.

The downward succession of the metals is roughly: (1) Copper ores from the surface to 840 ft.; (2) tungsten ores from 840 to 1,200 ft.; (3) tin ores from 840 to 2,040 ft. in the south-dipping lodes and possibly to 2,700 ft. in the north-dipping lodes.

Maclaren thinks that there may have been a blende-galena zone now eroded above the copper zone. He also notes that on the 1,176-ft. level of the Rogers lode, scheelite occurs in wolframite along cleavage cracks and as veinlets.

In the new Rogers lode, which was discovered underground, the average content of tin and tungsten ore per ton was as follows:

	Lbs. per Ton.	Length of Shoot on Level, Feet.
960-ft. level	25.4	391
1,140-ft. "	83.7	729
1,272-ft. "	110.9	625
1,440-ft. "	61.0	472

H. W. TURNER.

The Wolfram Mines of Mount Carbine, North Queensland. By LIONEL C. BALL. Pub. No. 251, Geol. Surv. of Queensland, Brisbane, 1915.

The geological formations of the district are sedimentary slates and schists intruded by biotite-granite and muscovite-granite, and the ores are found in pegmatite dikes which are intruded into the schist series. Intrusive granite occurs at the surface within a half mile from the Mount Carbine workings and Ball thinks that granite will be encountered in the workings at the depth of a few hundred feet. The ore-bearing belt has a length of one and a half miles and a width of one-fourth of a mile. The pegmatite ore veins vary in width from mere threads to bodies six feet thick, but those that were being worked in 1912 were mostly less than two feet in thickness.

Quartz is the chief gangue mineral and the wolframite occurs both in the quartz and in orthoclase. Wolframite is the chief valuable mineral with smaller amounts of scheelite and near the surface tungsite, tungstate of manganese and iron and tungstate of lead. Associated minerals are muscovite, tourmaline, beryl, pyrite, molybdenite, and cassiterite. The total product of wolfram concentrate up to 1913 is estimated at 1,000 tons.

H. W. TURNER.

SCIENTIFIC NOTES AND NEWS[1]

E. L. BRUCE, of the Geological Survey of Canada, has been given leave of absence to deliver a course of lectures at the University of Manitoba.

BURTON HARTLEY, Capt. 45th Artillery, has been released and has opened an office with J. E. Thomas, under the name of Thomas & Hartley, Consulting Geologists, San Antonio, Texas.

HOYT S. GALE, geologist of the U. S. Geological Survey, is en route to Europe as a member of a commission sent by Secretary Lane to study reconstruction problems. Mr. Gale's special mission is the investigation of potash supplies available for the United States, and he will visit deposits in Alsace, Spain and elsewhere.

LIVINGSTON WERNECKE, geologist of the Alaska Treadwell and Alaska Juneau mines, is giving a course of lectures at the College of Mines, University of Washington, on the mining geology of the Juneau district.

SYDNEY J. JENNINGS has gone to Mexico City to confer with the Mexican division of the A. I. M. E. regarding problems of mining engineers in that country.

HORACE V. WINCHELL has been elected president of the American Institute of Mining Engineers.

J. D. FALCONER, lecturer in geography in Glasgow University, is to be the first director of the Geological Survey of Nigeria.

MAJOR CLEM D. WEBB, proprietor of the *South African Min-*

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

ing Journal, has returned to Johannesburg after three years active service in the British Army to resume his former connections with that publication.

W. H. WEED has been in Tonopah recently.

HEATH M. ROBINSON has recently resigned from the United States Geological Survey, and is now employed by Mr. F. Julius Fohs, consulting oil geologist, with headquarters at 60 Broadway, New York City.

LT. OWEN LETCHER, on the conclusion of his duties in East Africa, resumed his position as mining editor of the *South African Mining Journal.*

W. H. ALDRIDGE is president of the Texas Gulf Sulphur Co., of New York.

COLONEL T. W. EDGEWORTH DAVID, D.Sc., F.R.S., gave a lecture before the Geological Society of London on February 26 on "Geology on the Western Front."

A. E. KITSON, director of the Geological Survey of the Gold Coast, is now on tour in the Colony. He is also supervising the geological work of part of Togoland.

A. W. STICKNEY has left for Vladivostok.

VICTOR ZIEGLER has resigned from the Colorado School of Mines and will open an office as consulting geologist in the Empire Building, Denver.

L. D. RICKETTS and JOHN C. GREENWAY were recently at Santa Barbara.

HOWLAND BANCROFT, of Denver, was in San Francisco on his way to Mexico.

OLAF P. JENKINS, geologist, Arizona Bureau of Mines, is preparing a classified bibliography on Arizona geology, which will probably be completed before next autumn.

C. K. LEITH, professor of geology at the University of Wisconsin, has returned from Paris, where he served as mineral adviser in the Economic Section of the American Peace Commission, and will resume his work at Madison. Prior to going to Paris, Professor Leith performed mineral advisory work for the Shipping War Industries, and War Trade Boards in Washington, D. C.

E. K. SOPER is now geologist with the Trinidad Petroleum Development Co., P. O. Box 175, Port of Spain, Trinidad, B. W. I.

JON A. UDDEN is now chief geologist, Sinclair Gulf Oil Co., Burk Burnett Building, Ft. Worth, Texas.

CHARLES CAMSELL, head of the Geological Survey in British Columbia, is in Ottawa to arrange for field work for the coming season.

COURTENAY DEKALB sailed for Spain on March 25 on a special commission for the U. S. Department of Commerce.

IRA JORALEMON, Major in the A. E. F., has returned from France to Berkeley and shortly will resume his duties as geologist to the Calumet & Arizona Copper Company.

J. MACKINTOSH BELL, lieutenant-colonel in the British Army, will resume his professional work as mining geologist. He is in Almonte, Ontario, Canada.

W. H. BLACKBURN, general manager for the Tonopah Mining Co., is in Nicaragua at the company's Eden Mine.

KIRBY THOMAS is making an examination of chrome properties at Black Lake, Quebec.

CHESTER NARAMORE resigned his position as chief petroleum geologist with the Bureau of Mines on February 1, 1919, to accept a position with the Union Petroleum Co., Philadelphia, Pa.

MAX ROESLER is connected with the U. S. Geological Survey at Washington, D. C.

G. D. DELPRAT, manager of the Broken Hill Proprietary, has arrived from Australia.

W. R. INGALLS has taken an office at 115 Broadway, New York.

SCOTT TURNER is at Toronto.

GEORGE R. ALLEN, president of the Chosen Minerals Co., has arrived in the United States from Keijyo, Korea.

W. H. BLACKBURN, consulting engineer of the Tonopah Mining Co., Nev., is in Nicaragua on business pertaining to the Eden Mining Co., a subsidiary.

MYRON A. FOLSOM is in the Ranger oilfield of Texas.

ALBERT BURCH, of the firm of Burch, Caetani & Hershey, of San Francisco, recently made a preliminary examination of the Church-Union group of gold-quartz claims in Placerville, Cal.

DAVID D. IRWIN has taken a position in the office of the president of the Phelps-Dodge Corporation, at Douglas, Arizona.

L. R. SCHEURER, professor of mining engineering, has accepted a position with the North Georgia Agricultural College, having resigned at the Missouri School of Mines.

D. R. SEMMES, formerly a professor of geology at the Texas A. & M. College, has opened an office at 47 Petroleum Building, Fort Worth, Texas.

ROBERT D. ADAMS, the Californian chrome and magnesite engineer, who has been in northern Russia for several months with the Canadian forces, has been awarded the D. S. O.

JOHN C. GREENWAY, lieutenant-colonel, has returned from Europe and is at Ajo, Arizona, recovering from the effects of gas.

E. E. BARKER has been transferred to Morococha as superintendent of the Cerro de Pasco Copper Corporation.

POPE YEATMAN and Edwin S. Berry have removed their engineering offices from 60 Broadway to Room 708, 111 Broadway, New York.

PHILIP N. MOORE has been appointed engineer member of the

War Minerals Relief Commission to adjust claims growing out of governmental efforts to stimulate production of war minerals. J. F. Shafroth is the chief engineer of the commission and is now organizing the examining staff.

L. C. STUCKEY reached New York on his way to the Mazipil copper mine, Coahuila, Mexico.

E. H. DICKENSON, formerly assistant superintendent of mining and prospecting for the Tata Iron and Steel Co., has been appointed general manager of mines for that company at Sakchi, India.

HARRY D. GRIFFETHS is consulting engineer with the Kanbauk (Burma) Wolpam Mines, Ltd., at 34 Great St. Helens, London, E.C., England.

L. F. S. HOLLAND is connected with the Arizona Mines & Reduction Co., at 627 Citizens National Bank Building, Los Angeles, California, in the capacity of consulting engineer.

WALLACE E. PRATT is now chief geologist at the Humble Oil & Refining Co., Box 1352, Fort Worth, Texas.

JOHN C. ROGERS has left the employ of the Canadian Copper Co., and is now with the International Nickel Co., of Canada, Ltd., Copper Cliff, Ont., Canada.

O. N. SCOTT, of Toronto, who has been in Vancouver the last ten months as assistant to the director of the Department of Aëronautical Supplies, has returned to Toronto.

K. POMMERANTZ has resigned his position with the South American Metal Co. (Fundicion de Guayacan) and has opened offices at Casilla 489 Santiago de Chile, Chile, S. A., as an independent consulting engineer.

WILBERT B. CERTON has opened an office of information on mines in Central America at Tegucigalpa, Honduras.

CHARLES P. PERIN, connected with the Tata iron industry in India, has been appointed assessor of damage done to the Belgian and French iron mines and steel works during the German occupation.

P. A. ROBBINS, lately manager of the Hollinger at Porcupine, has opened an office as consulting engineer at Hobart Building, San Francisco.

PERCY E. BARBOUR is now assistant secretary of the American Institute of Mining Engineers.

EDWARD DAWSON, consulting engineer, Cardiff, has been elected president of the South Wales Institute of Engineers.

R. T. SCHRAUBSTADTER, of St. Louis, has been examining a mine in Plumas County, California.

JASPER T. ROBERTSON has opened an office in the Hobart Building, San Francisco.

J. H. MCMILLAN has resigned as district inspector of mines for British Columbia and will become general manager for the Jasper Park Collieries, Ltd., in Alberta.

EDWARD S. DAVIS, chief of the Fuel Oil Section, Bureau of Oil Conservation, after six months of service has returned to Tate, Jones & Co., Inc., Pittsburgh.

HERBERT C. HOOVER, who was recently named Director General of Allied Relief, under the commission sitting in Paris, has been appointed by President Wilson to be Director General of the American Relief Administration, with full authority to supervise the expenditure of $100,000,000 recently voted by Congress for European famine relief.

H. W. EDMONDSON, recently a captain in the U. S. Engineering Corps, left New York for Oatman, Arizona, where he will examine the Vivian Leyland group of mines.

LINDESAY C. CLARK, general manager of the Briseis Tin & General Mining Co., has been commissioned by the Victorian Government to report on the best method of mining the Morwell brown coal deposits.

H. E. WHITFIELD, professor of mining in the University of Western Australia, is returning to Australia after three years of war duty for the Ministry of Munitions, both in England and in the United States.

G. S. CORSTORPHINE, principal of the South African School of Mines and Technology, and a leading South African geologist, died on January 25.

THE Geological Society awards are as follows: Wollaston Medal to Sir Aubrey Strahan, director of the Geological Survey of England; Lyell Medal to Dr. W. F. Hume, director of the Egyptian Geological Survey; Bigsby Medal to Sir Douglas Mawson; Woolaston Fund to Dr. A. L. Du Toit, of the Geological Survey of South Africa; Lyell Fund to John Pringle and Dr. Stanley Smith.

AT the February meeting of the Tulsa section of the American Institute of Mining Engineers, Dr. Willis T. Lee, head of the geological department of the University of Oklahoma, obtained pledges from all field geologists present to give lectures in their special subjects as a part of Dr. Lee's course in practical oil geology at the university.

PREPARATIONS are being made by the War Department to conduct research work on nitrates at the American University, near Washington. This is being done to take advantage of the equipment and facilities which are being abandoned by the Chemical Warfare Service.

THE fourth annual meeting of the American Association of Petroleum Geologists was held at Dallas, Texas, March 13–15, and attended by more than two hundred petroleum geologists and several visitors, among whom were David White, I. C. White, Ralph Arnold and Charles Schuchert.

Papers were presented by the following: J. A. Udden, on "Subsurface Geology of North Central Texas"; C. R. Eckes, on "Cuttings from the Duffer Well at Ranger"; F. B. Plummer, on "Cuttings from the Goode and Dye Wells in Young and Palo Pinto Counties"; W. E. Pratt, on "Notes on Relation of Surface to Subsurface Structure and Petroleum Accumulation in North Texas"; David White read a paper by G. H. Girty on "The Bend Formation and its Correlation," and made an address regarding accumulation of petroleum reserves in foreign

countries by American companies; M. L. Fuller, "On the Water Problems of the Bend Series and its Effect on the Future Production and Flooding of Oil Sands," also an illustrated lecture on China; J. W. Beede, "Notes on the Structures and Oil Showings in the Red Rocks of Coke Co., Texas"; T. W. Gregory, "Gas Conservation and Distribution under the U. S. Fuel Administration"; W. L. Matteson, "Review of Developments in Central Texas Oil Fields"; W. R. Berger, "Extent and Interpretation of Hogshooter Gas Sand"; R. B. Moore, "Correlation of the Bend"; Sidney Powers, "Geologic Work of the American Expeditionary Forces"; E. L. Blasch, "Unconformaties in Oklahoma"; Ralph Arnold, "Problems of Oil Lease Valuation," and an evening address on the "Policy of the Federal Government in Valuation and Taxation of Oil Properties"; C. H. Beall, "Factors in the Valuation of Oil Lands"; R. H. Johnson, "Decline Curve Methods," and "Statistical Investigation of the Influence of Structure on Oil and Gas Production in the Osage Nation"; E. W. Shaw, "Valuation of Gas Properties"; E. H. Sellards, "Structural Conditions in the Oil Fields of Baxar Co., Texas"; Charles Schuchert illustrated lecture on contacts.

The following papers were read by title: D. F. MacDonald, "Notes on the Stratigraphy of Panama and Costa Rica"; Geo. E. Burton, "Design for a Log Meter"; G. Sherburne Rogers, "Oil Field Waters"; J. W. Bostwick, "The Saratoga, Texas, Oil Field"; Earl A. Trager, "Laboratory Methods for the Examination of Well Cuttings"; Robert T. Hill, "History of Geologic Exploration in the Southwest."

The following officers were elected for the coming year: Dr. I. C. White, president; Irving Perrins, vice-president; Prof. C. E. Decker, secretary-treasurer; Charles H. Taylor, editor.

ERRATA.

No. 1, January–February number, 1919: In the paper "The Veins of Chañarcillo, Chile," by W. L. Whitehead, pp. 1–45, the word *hypergene,* used throughout the paper, should be written *hypogene.*

No. 1, January–February number, 1919: In the discussion "American Petroleum Geologists in Europe," the author's name was incorrectly spelt as *E. D. Golyer* instead of *E. DeGolyer.*

No. 2, March–April number, 1919: Pages 176–178 are replaced by pages 262–264 of this number.